NAVIGATION STUDY FOR

JACKSONVILLE HARBOR, FLORIDA

FINAL INTEGRATED GENERAL REEVALUATION REPORT II

AND

SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT

APPENDIX A

ATTACHMENT J

ENGINEERING – Hydrodynamic (ADCIRC) Modeling for Storm Surge and Sea Level Change

Hydrodynamic Modeling for Storm Surge and Sea Level Change:
Jacksonville Harbor Navigation Study

Duval County, FL
August 2013
(Revised Sept 2013)

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Hydrodynamic Modeling for Storm Surge and Sea Level Change:
Jacksonville Harbor Navigation Study

Prepared for

U.S. Army Corps of Engineers, Jacksonville District

by

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1.0 INTRODUCTION

The ADCIRC+SWAN hydrodynamic modeling for the Jacksonville Harbor Navigation Channel Design studied various Jacksonville Harbor channel depth configurations and sea level rise (SLR) scenarios. The ADCIRC+SWAN modeling applied synthetic storm forcings that produce 50- and 100-year water levels near the project as described in Taylor Engineering. The ADCIRC+SWAN model (Dietrich et al., 2011) couples the ADCIRC hydrodynamic model (Luettich and Westerink, 2006; Luettich et al., 1992) with the SWAN spectral wave model (Booij et al., 1999). The ADCIRC model component of the SWAN+ADCIRC model supplies SWAN with the required input forcing data — wind speeds, water levels, and currents computed at the vertices — at the given time step. ADCIRC interpolates input wind fields spatially and temporally, projects these winds to the computational vertices, and then passes the wind fields to SWAN. SWAN applies water levels and ambient currents computed in the ADCIRC model component to recalculate the water depth and all related wave processes — wave propagation, depth-induced breaking, etc. (Dietrich et al., 2011) — and passes information in the form of radiation stress back to the ADCIRC model.

This report presents results of the ADCIRC+SWAN modeling evaluation of various combinations of forcing, water level, and channel configurations. The modeling applies a ADCIRC+SWAN model mesh developed for this study. The study team refined and adapted the ADCIRC mesh for the St. Johns River intertidal zone developed for salinity modeling and appended it to the Georgia / Northeast Florida FEMA ADCIRC+SWAN mesh to facilitate storm surge modeling for the widening and deepening of the lower St. Johns River navigation channel. Appendices A and B detail the development of the ADCIRC+SWAN mesh.

The application of various sea level change scenarios in combination with the model forcing and channel configurations allows evaluation of future scenarios. Model results presented as maximum water levels, water level differences for like forcing but varied channel configuration, and water level time series at specific locations allows evaluation of the various channel configurations, storm forcing, and water levels. Figure 1.1 provides the major features of the Jacksonville Harbor Navigation Channel and surrounding area.

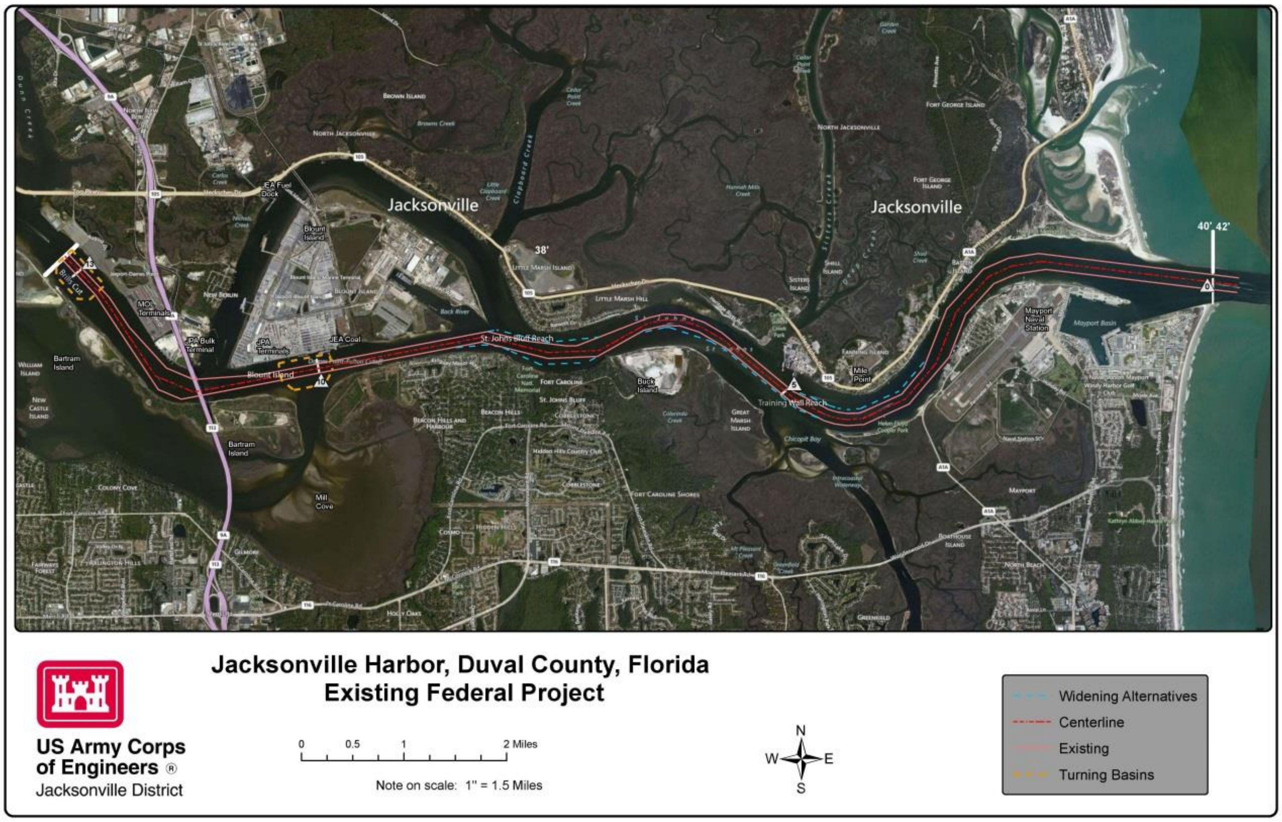

Figure 1.1 Jacksonville Harbor Navigation Channel Features

2.0 SCENARIOS EVALUATED

The scenarios evaluated with the ADCIRC+SWAN model allow examination of the effects of channel configuration, storm forcing, and sea level on the storm surge in the vicinity of the Jacksonville Harbor Navigation Project. Table 2.1 presents the details of each of the 10 scenarios evaluated with the ADCIRC+SWAN model. The 2068 Future without project (2068 FWOP) scenarios include the baseline channel configuration which is defined as the existing 2010 channel depths, the recently constructed U.S. Navy Mayport deepening, and the Milepoint project. The 2068 Tentatively Selected Plan 47-ft (2068 TSP 47 ft) scenario includes the 47 ft channel configuration which is defined as the 47 ft-MLLW depth within the project channel plus advanced maintenance depths. The simulations with sea level changes of 0.4 and 1 ft where focused on the projects effect on storm surge including the cumulative effect of historic and intermediate sea level changes per USACE guidance for this study. The simulations with sea level changes of 2 ft and 6 ft were focused on an evaluation of sea level change impacts on storm surge.

SLR scenarios include a 0.4-ft scenario to represent the USACE historic 50-yr projection, 1.0-ft for the USACE intermediate 50-yr projection, 2.0-ft to represent the USACE high 50-yr projection, and 6.0-ft for an extreme 100-yr projection.

Table 2.1 Scenarios Evaluated with the ADCIRC+SWAN Model

Scenario #	Scenario Description	Sea Level Change	Storm Forcing Return Period
1	2068 FWOP	0.4 ft	50-yr
2	2068 FWOP	0.4 ft	100-yr
3	2068 TSP 47 ft	0.4 ft	50-yr
4	2068 TSP 47 ft	0.4 ft	100-yr
5	2068 FWOP	1 ft	50-yr
6	2068 FWOP	1 ft	100-yr
7	2068 TSP 47 ft	1 ft	50-yr
8	2068 TSP 47 ft	1 ft	100-yr
9	2068 FWOP	2 ft	50-yr
10	2068 FWOP	6 ft	50-yr

In an earlier portion of this study, the study calibrated and validated the ADCIRC+SWAN model to ensure the model reasonably reproduced measured storm surge levels in the project area. Appendix C details the analysis conducted by the study team to select storms appropriate for the ADCIRC+SWAN model calibration and validation. Application of the selected calibration and validation storms — Hurricane Dora (1964) and Hurricane Frances (2004) — allowed the study team to document the models capability to reproduce measured water levels in the project area. Appendix D details the calibration and validation process and results. The study team applied the calibrated and validated ADCIRC+SWAN model to develop storm forcing that produced the target 50- and 100-yr water levels in the project area based on Dean et al. (1991) total storm tide values for various return periods along three shore-perpendicular transects in Duval County, FL. The total storm tide estimates include the contributions of wind stress, barometric pressure, dynamic wave setup, and astronomical tide (See Appendix E). The resulting 50- and 100-yr water levels equaled 9.4 ft-NAVD88 and 12.0 ft-NAVD88 offshore of the St. Johns River mouth for a no sea level rise scenario (Appendix E).

3.0 SCENARIO ANALYSIS RESULTS

This section provides results of the ADCIRC+SWAN model for the various scenarios evaluated (Section 2). Presentation of the results includes contour plots of maximum water surface elevation (WSE), contour plots of differences in maximum WSE for relevant scenarios, and times series of WSE for various locations near the project area. The contour plots of maximum WSE allow evaluation of water levels and inundation extents for each scenario. Contour plots of maximum WSE allow evaluation of changes to the channel configuration (for similar storm forcing and SLR values). Time series plots show how the tide and surge hydrographs at specific locations vary with different channel configurations, forcing, and SLR values.

Figures 3.1 and 3.2 present maximum 50- and 100-year (yr) WSE for the baseline channel configuration and 0.4 ft SLR (Scenarios 1 and 2). Figure 3.1 shows maximum water levels near 10 ft-NAVD88 offshore for the 50-yr storm forcing results. The figure shows maximum water levels near 6.5 ft-NAVD88 in the vicinity of the Dames Point Bridge with significant areas of inundation in the marshes to the north. Figure 3.2 shows maximum 100-yr storm water levels near 12.5 ft-NAVD88 offshore with breaching of the barrier island near Jacksonville Beach. Near the Dames Point Bridge, maximum water levels approach 9.2 ft-NAVD88 with increased areas of inundation in the marshes to the north.

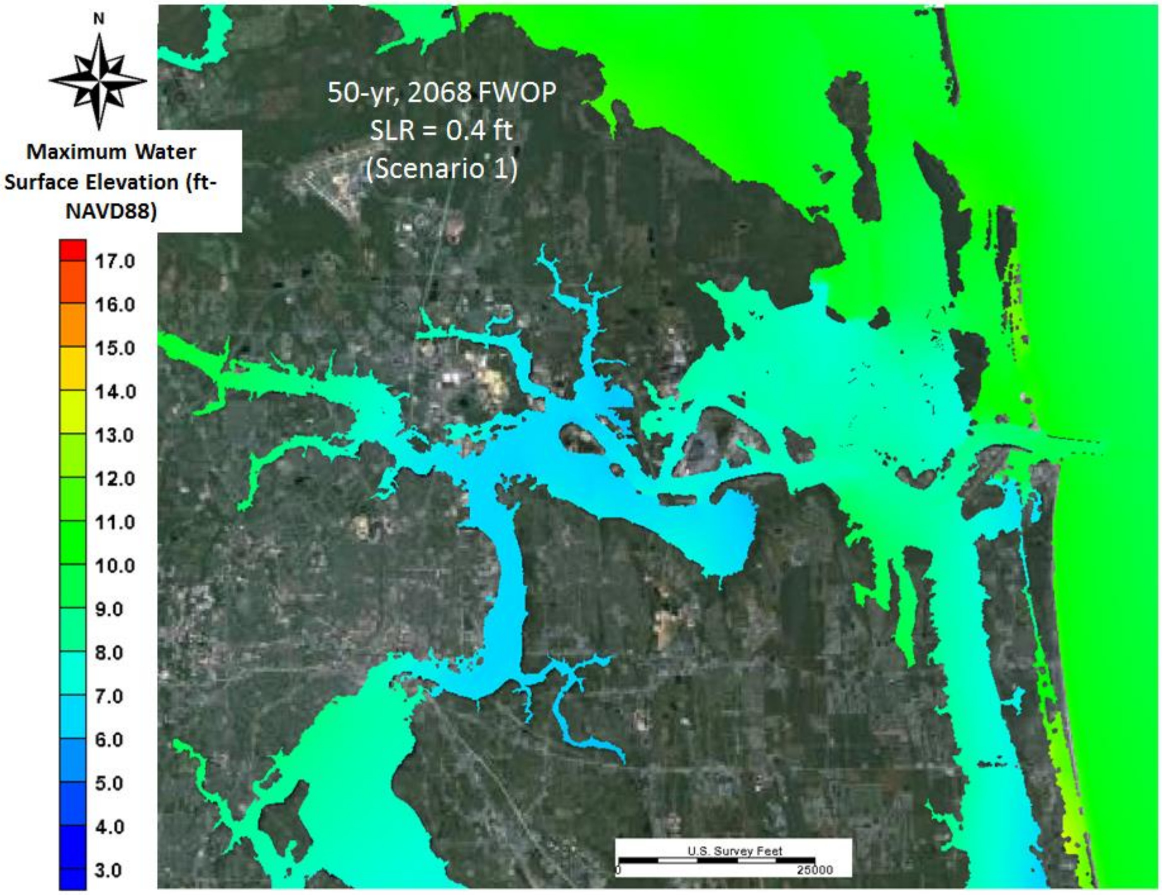

Figure 3.1 Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 1

Scenario 3 simulates the same storm forcing and SLR as Scenario 1, but with the channel deepened to 47 ft. The ADCIRC+SWAN water levels for Scenario 3 show similar values to Scenario 1 with minimal differences (< 0.5 ft) in the project vicinity. Figure 3.3 shows the differences in maximum WSE between Scenario 3 and Scenario 1. The results show that a 50-yr storm with a SLR of 0.4 ft produces slightly higher maximum water levels in the vicinity of the deepened (47-ft) channel. Differences generally decrease with distance from the deepened channel areas, as expected.

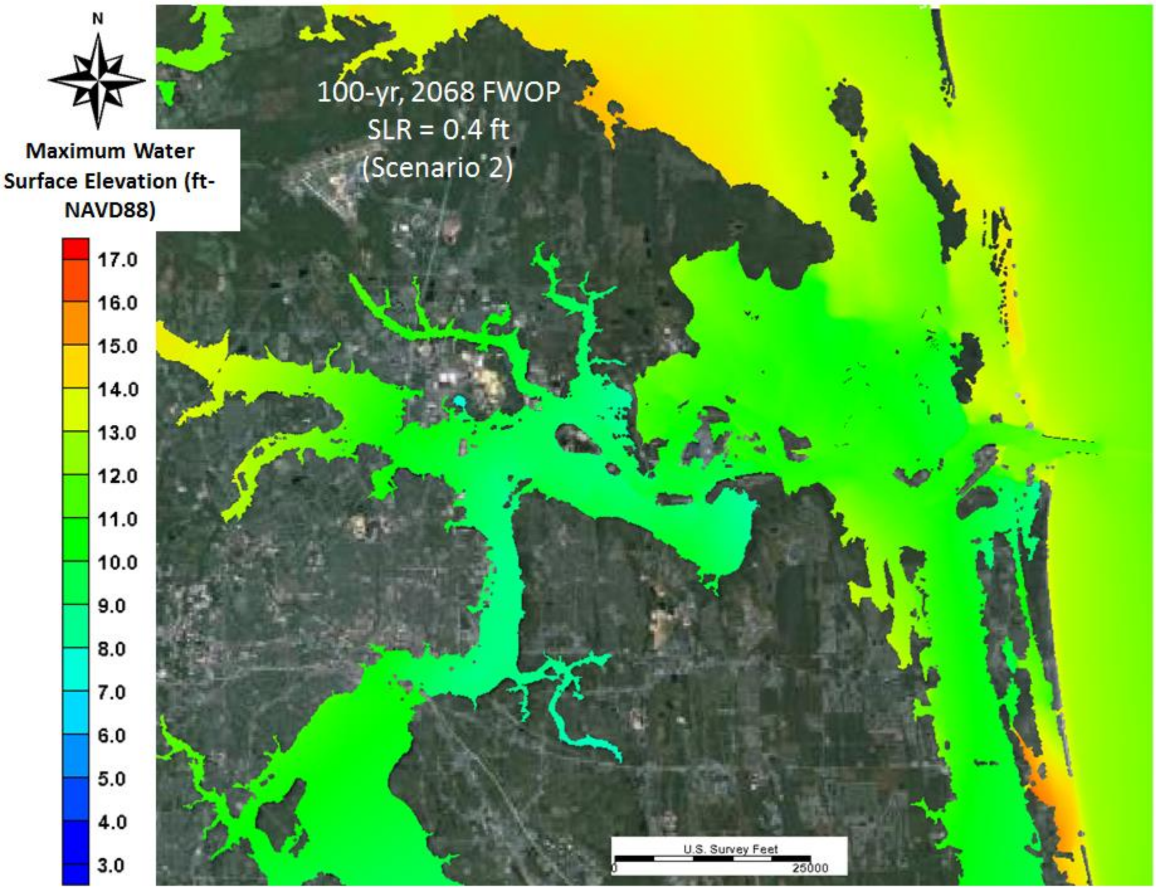

Figure 3.2 Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 2

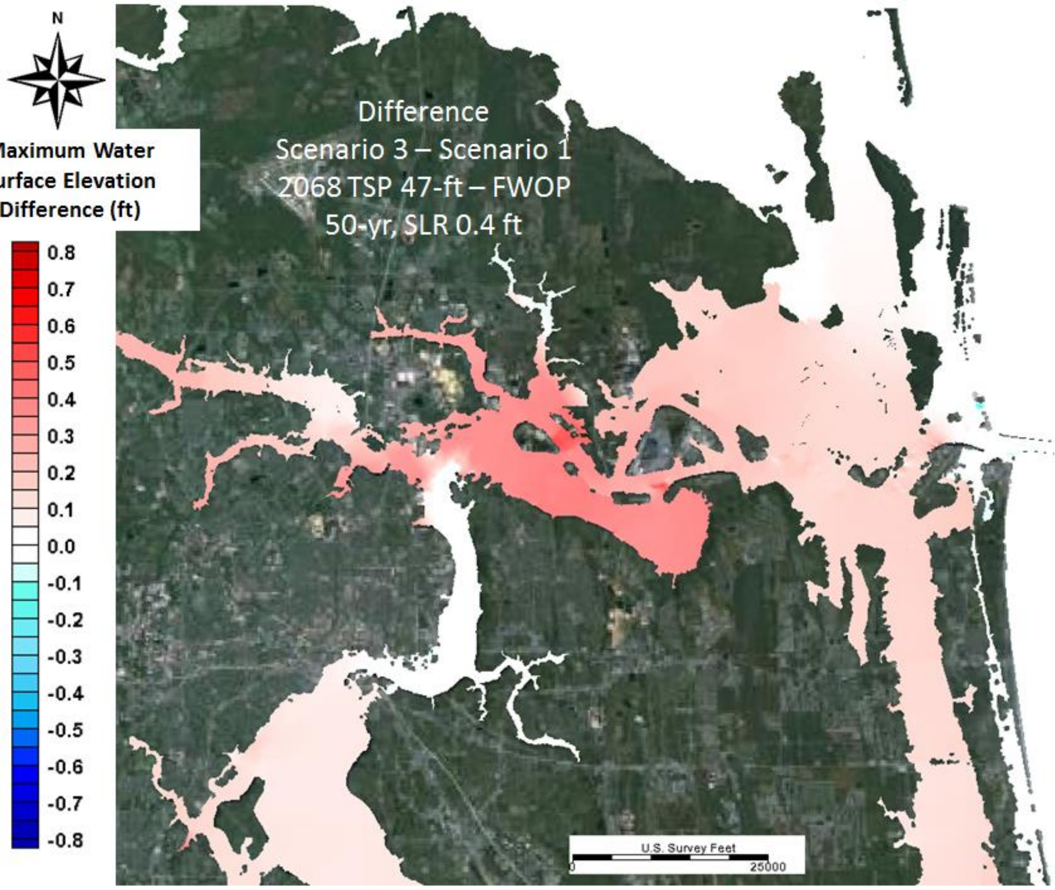

Figure 3.3 Difference in Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 3 Minus Scenario 1

Scenario 4 simulates the same storm forcing and SLR as Scenario 2, but with the channel deepened to 47 ft. The ADCIRC+SWAN water levels for Scenario 4 show similar values to Scenario 2 with minimal differences in the project vicinity; generally near 0.25 ft with isolated areas near 0.5 ft. Figure 3.4 shows the differences in maximum WSE between Scenario 4 and Scenario 2. The results show that a 100-yr storm with a SLR of 0.4 ft produces slightly higher maximum water levels in the vicinity of the deepened (47-ft) channel. Differences generally decrease with distance from the deepened channel areas, as expected. Observed differences generally reach about 0.25 ft with some areas near 0.5 ft and several small isolated areas near the inundation front approaching 0.7 ft.

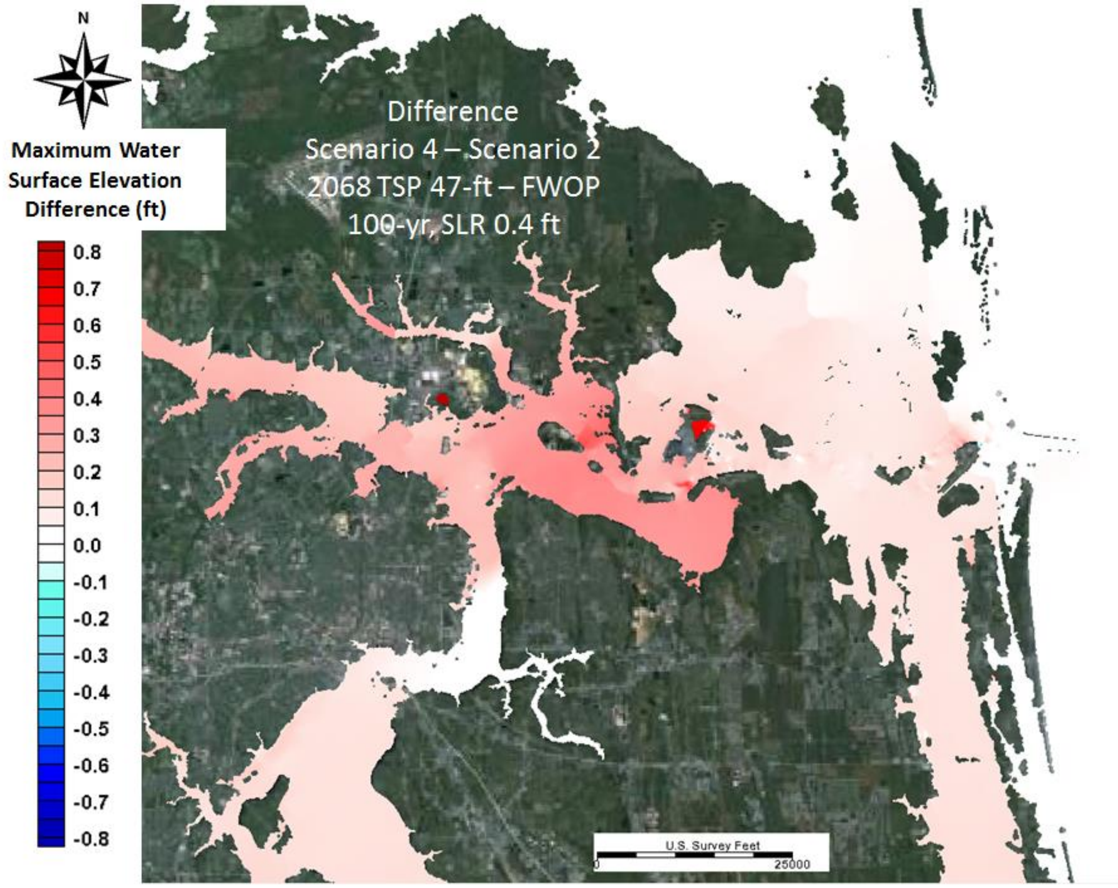

Figure 3.4 Difference in Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 4 Minus Scenario 2

Figure 3.5 shows locations selected for presentation of water level hydrographs for various scenarios evaluated with the ADCIRC+SWAN model. The locations selected allow evaluation of channel configuration and model forcing and SLR values for locations near the mouth of the St. Johns River, near Jacksonville Harbor, and locations near downtown Jacksonville. Figures 3.6 – 3.9 compare water level hydrographs for Scenarios 1 – 4 to demonstrate differences in tide and storm surge levels at specific locations. Figures 3.6 – 3.9 show similar tide forcing for all scenarios with increased storm surge for Scenarios 2 and 4 (100-yr storm). All figures indicate no significant difference between the baseline and 47-ft channel configurations under pre-storm tidal conditions. At Mayport, neither the 50- or 100-yr storm simulations show any significant difference between the surge levels for the baseline and 47-ft channel configurations. The Dames Point Bridge and Trout River stations show minimal increase in the peak surge levels for the 47-ft channel configuration. The San Marco station shows a slight increase in water levels before the surge for the 47-ft channel configuration; however, the surge indicates no significant difference between the baseline and 47-ft channel configurations.

Figure 3.5 Locations for Hydrograph Plots

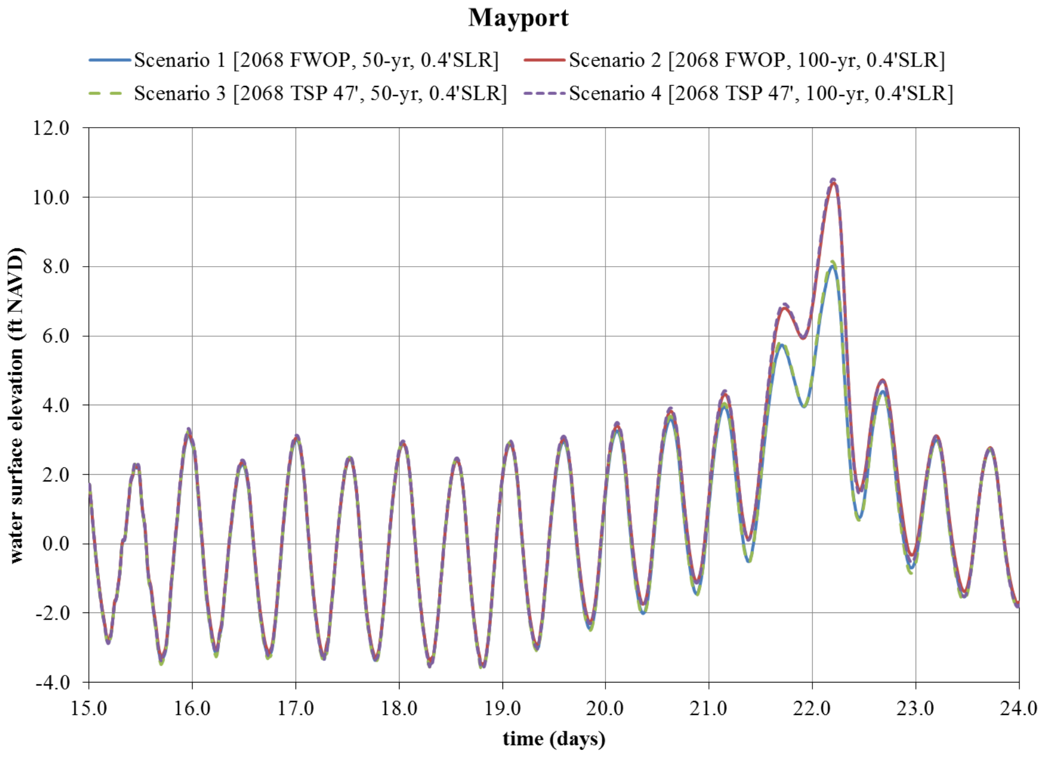

Figure 3.6 Hydrographs for Scenarios 1 – 4; Mayport

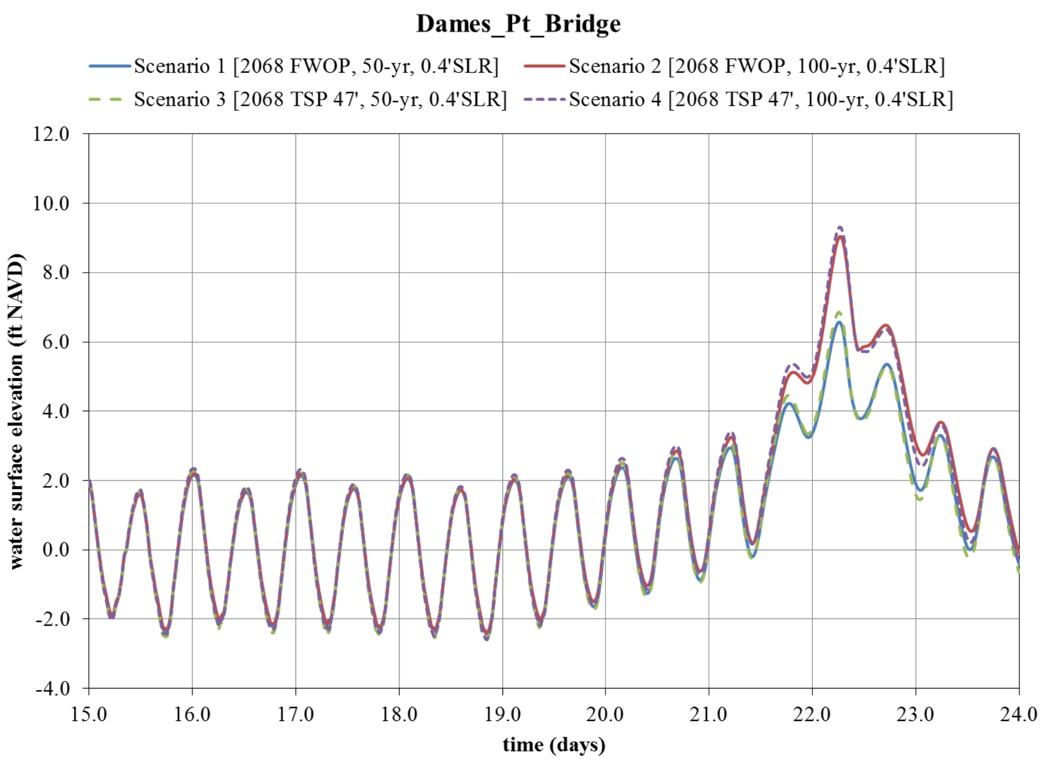

Figure 3.7 Hydrographs for Scenarios 1 – 4; Dames Point Bridge

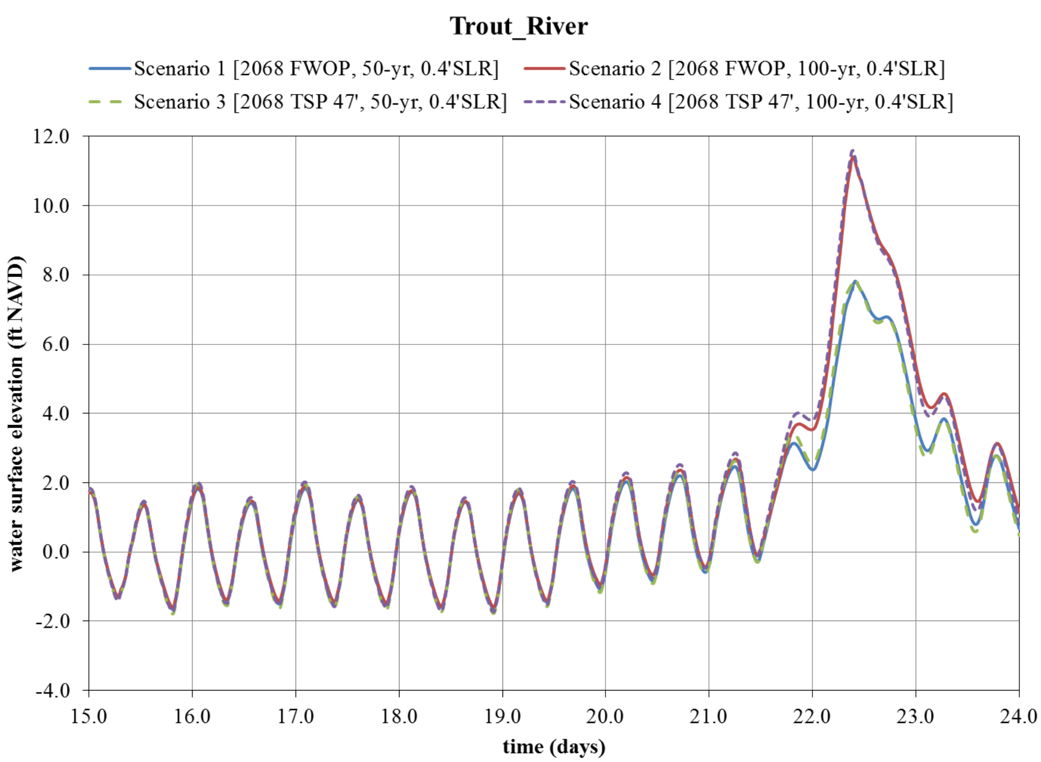

Figure 3.8 Hydrographs for Scenarios 1 – 4; Trout River

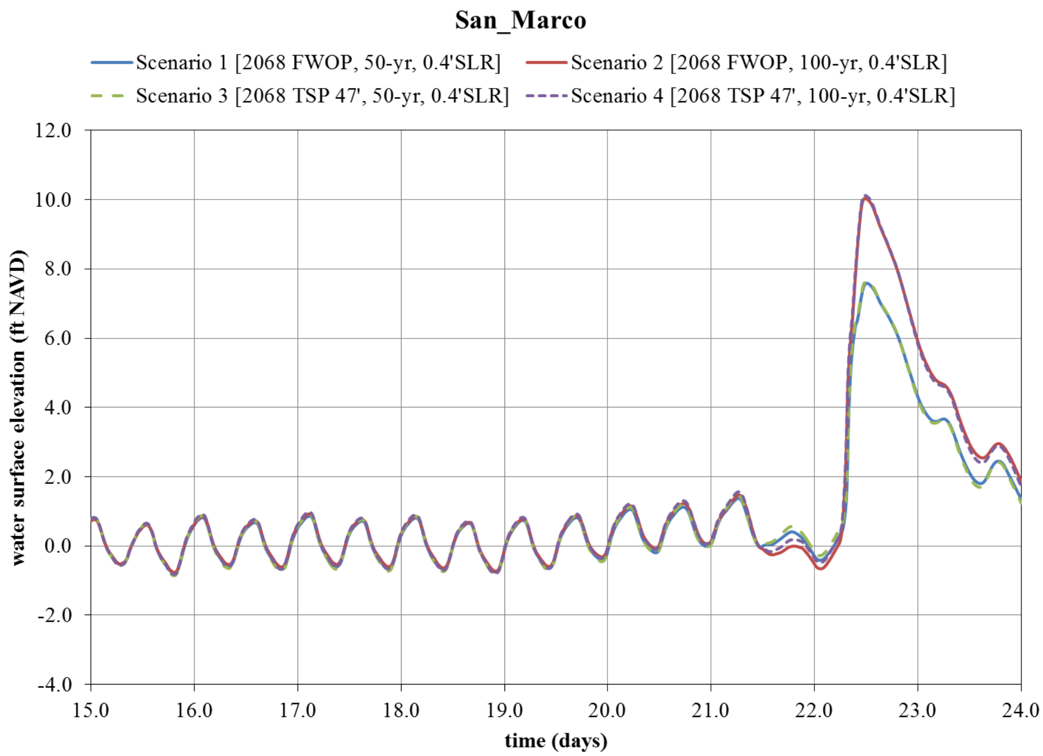

Figure 3.9 Hydrographs for Scenarios 1 – 4; San Marco

Figures 3.10 and 3.11 present the maximum 50- and 100-yr WSE for the baseline channel configuration and 1 ft SLR (Scenarios 5 and 6). Figure 3.10 shows maximum water levels near 10.3 ft-NAVD88 offshore for the 50-yr storm. The figure shows maximum water levels near 7.2 ft-NAVD88 in the vicinity of the Dames Point Bridge with significant areas of inundation in the marshes to the north. The figure shows some breaching of the barrier island near Jacksonville Beach. Figure 3.11 shows maximum 100-yr storm water levels near 12.8 ft-NAVD88 offshore and near 9.5 ft-NAVD88 in the vicinity of the Dames Point Bridge with significant areas of inundation in the marshes to the north and substantial breaching of the barrier island near Jacksonville Beach.

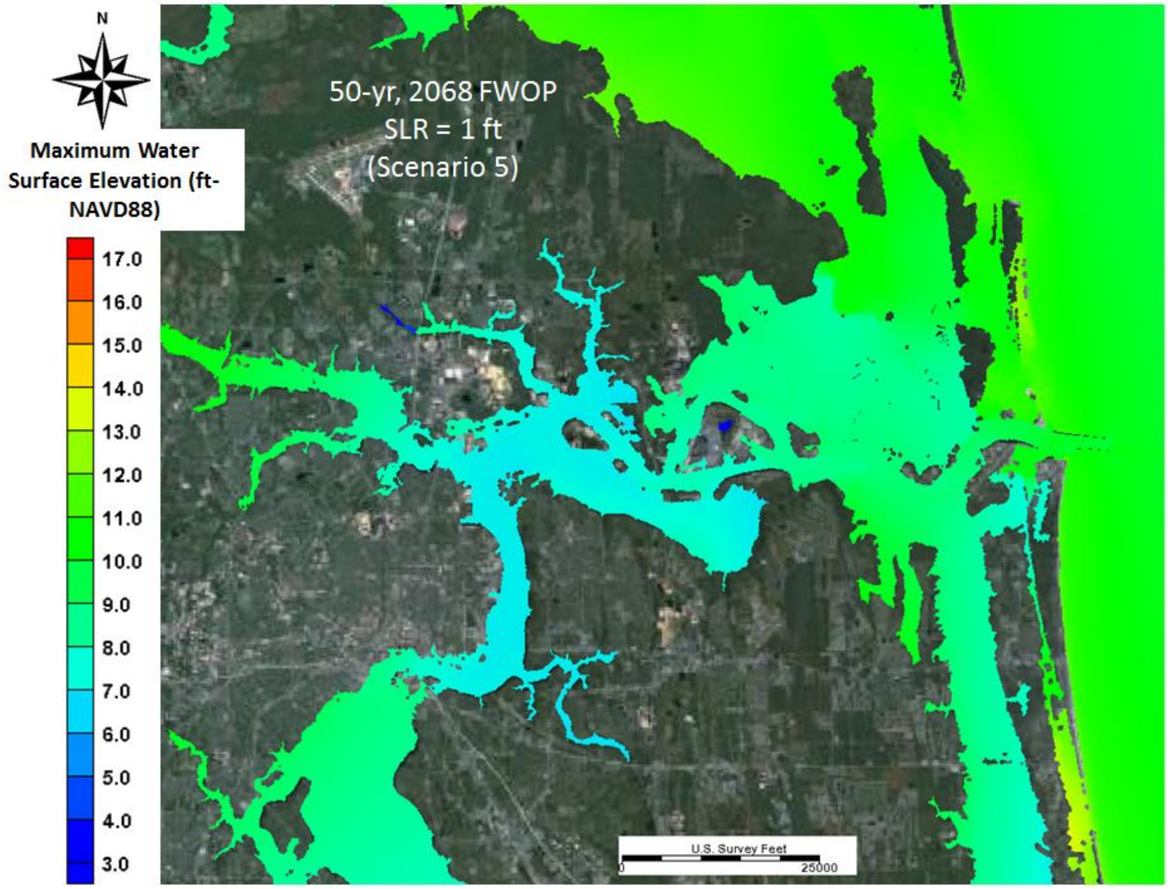

Figure 3.10 Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 5

Scenario 7 simulates the same storm forcing and SLR values as Scenario 5, but with the channel deepened to 47 ft. The ADCIRC+SWAN water levels for Scenario 7 show similar values to Scenario 5 with minimal differences in the project vicinity. Figure 3.12 shows the differences in maximum WSE between Scenario 7 and Scenario 5. The figure shows water levels increased about 0.25 ft with the 47-ft channel configuration. Isolated areas show increased water levels of about 0.5 ft. Differences generally decrease with distance from the deepened channel areas, as expected.

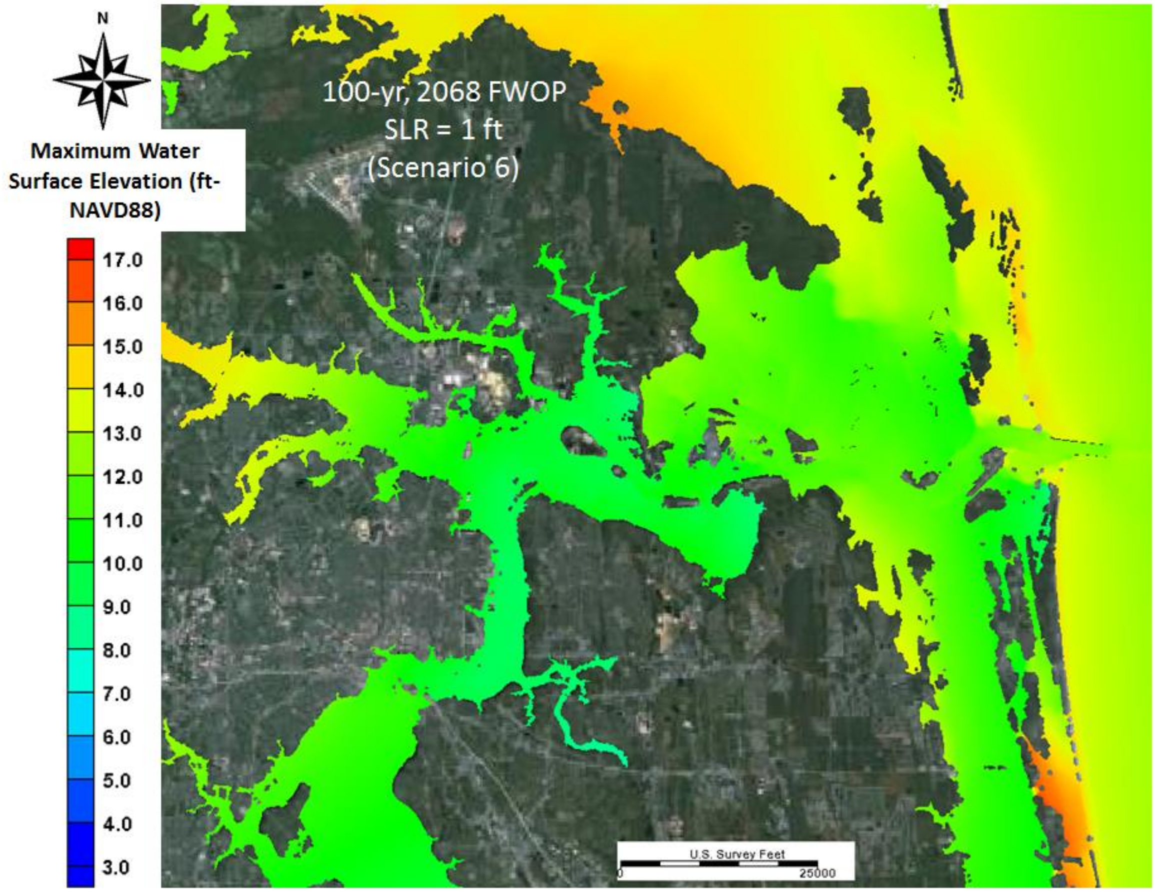

Figure 3.11 Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 6

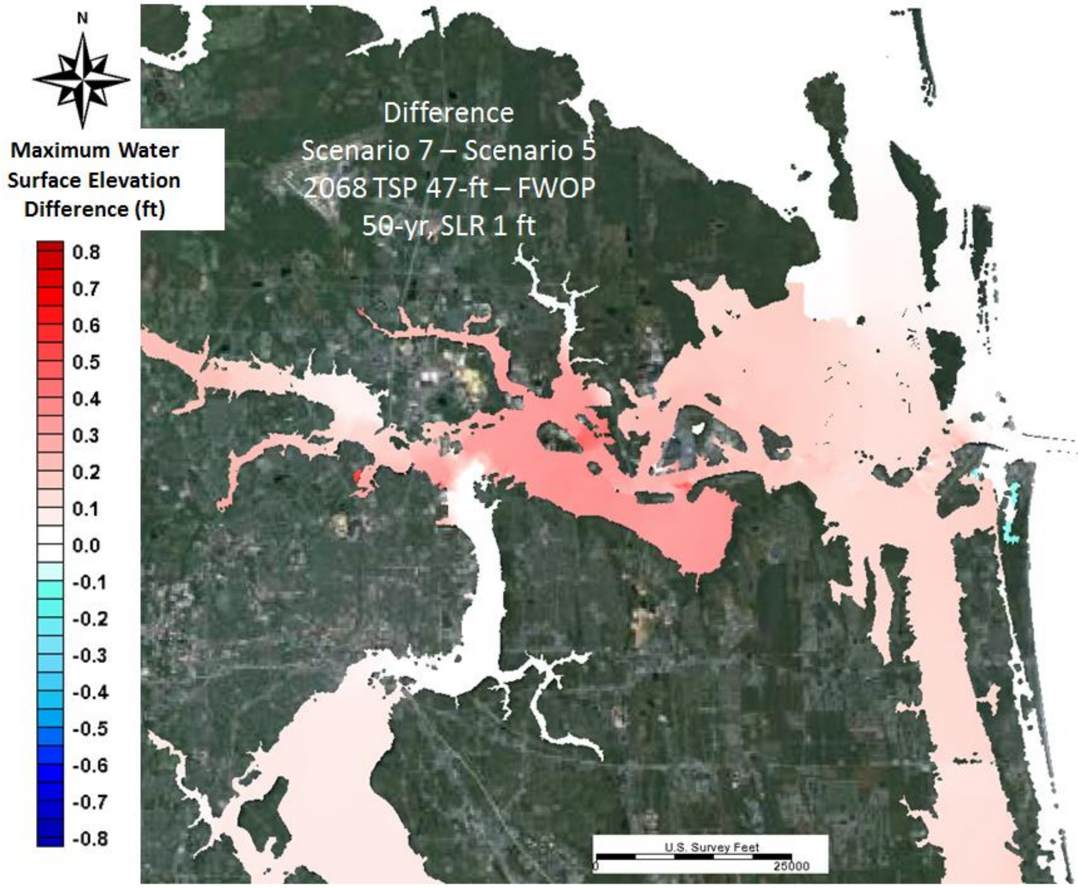

Figure 3.12 Difference in Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 7 Minus Scenario 5

Scenario 8 simulates the same storm forcing and SLR values as Scenario 6, but with the channel deepened to 47 ft. The ADCIRC+SWAN water levels for Scenario 8 show similar values to Scenario 6 with minimal differences (< 0.5 ft) in the project vicinity. Figure 3.13 shows the differences in maximum WSE between Scenario 8 and Scenario 6. The figure shows water levels increase about 0.25 ft with the 47-ft channel. Isolated areas show increased water levels of about 0.5 ft. As observed in the other difference plots, water level differences generally decrease with distance from the deepened channel areas, as expected.

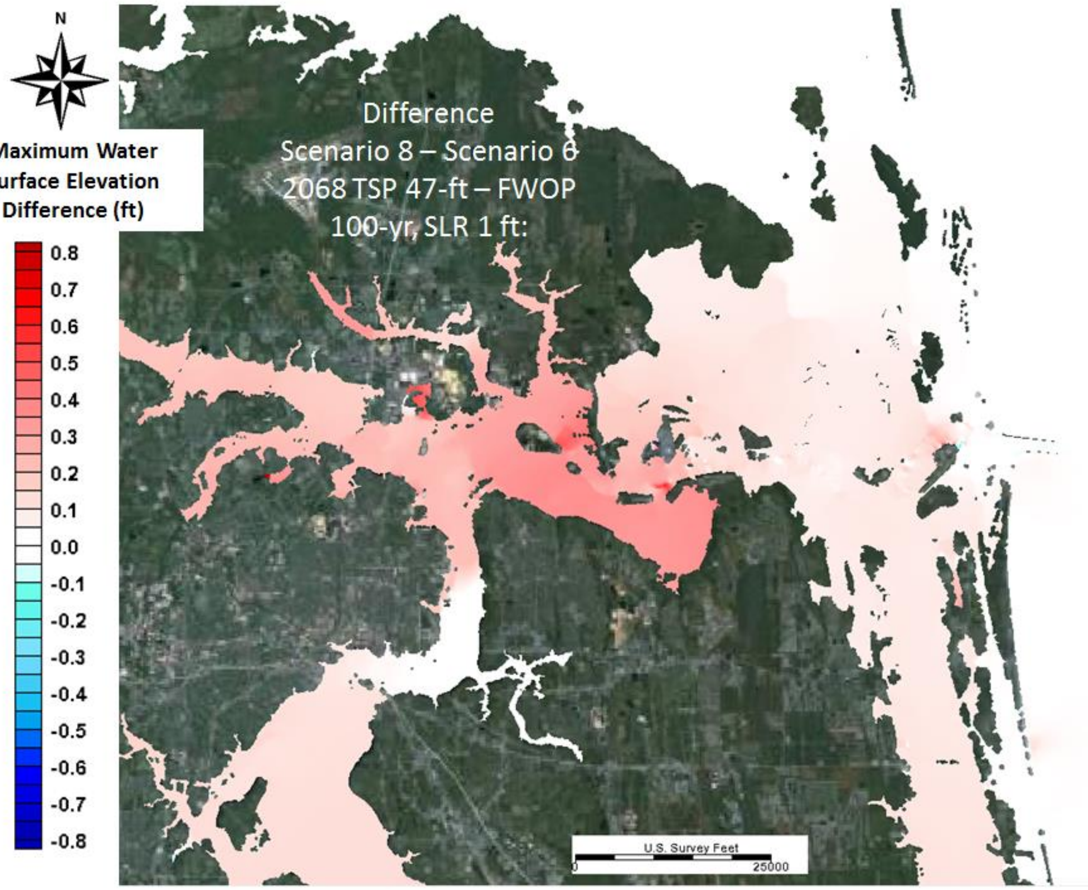

Figure 3.13 Difference in Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 8 Minus Scenario 6

Figures 3.14 – 3.17 compare water level hydrographs for Scenarios 5 – 8 to demonstrate differences in tide and storm surge levels at specific locations (Figure 3.5). Figures 3.14 – 3.17 show similar features to hydrographs plotted for Scenarios 1 – 4 with higher initial water levels (and peak surge values) caused by the higher SLR value. The channel deepening does not alter the general tide response, but does increase slightly the values near the peak surge (with comparable magnitude to the changes shown in Figures 3.3, 3.4, and 3.13).

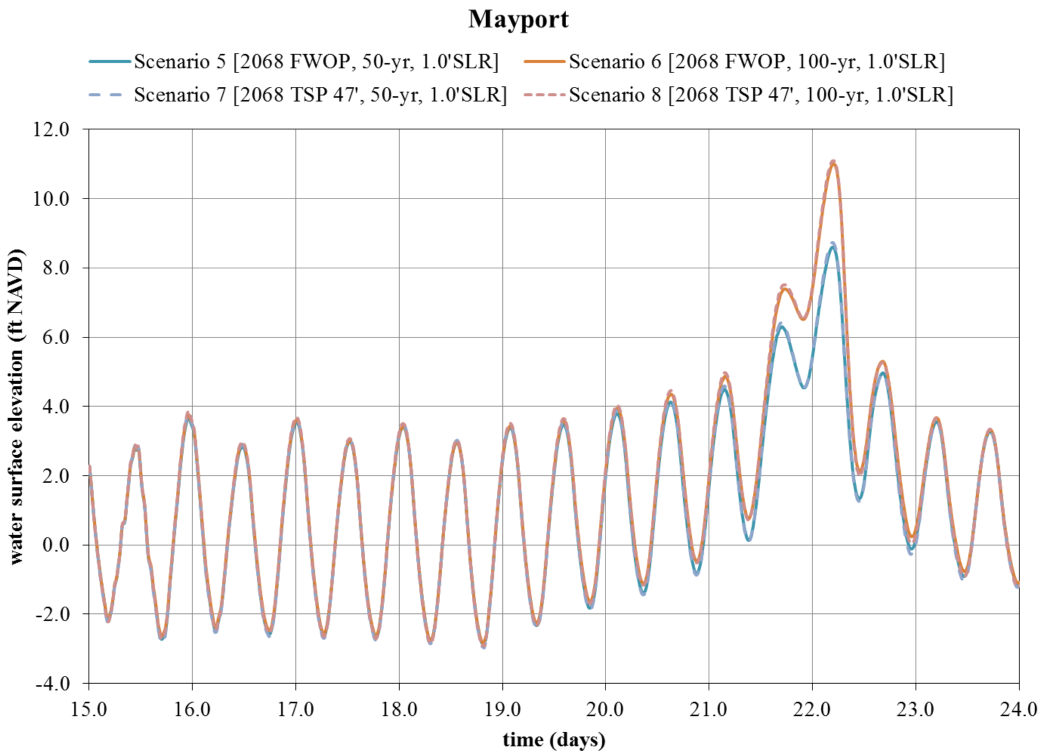

Figure 3.14 Hydrographs for Scenarios 5 – 8; Mayport

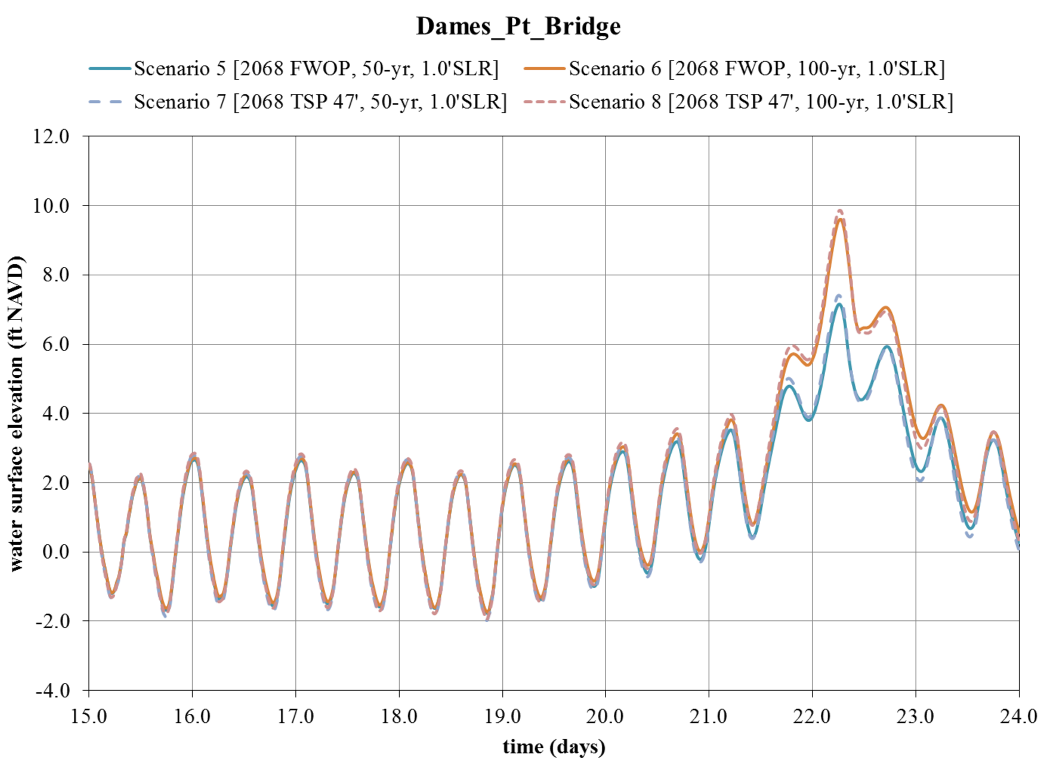

Figure 3.15 Hydrographs for Scenarios 5 – 8; Dames Point Bridge

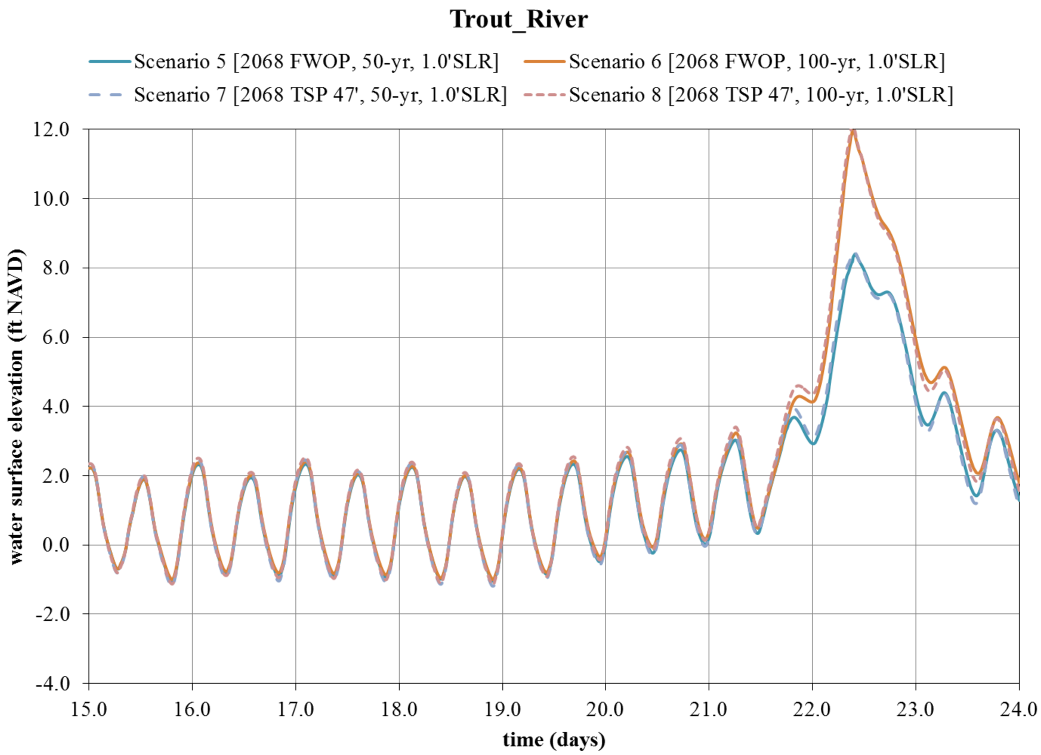

Figure 3.16 Hydrographs for Scenarios 5 – 8; Trout River

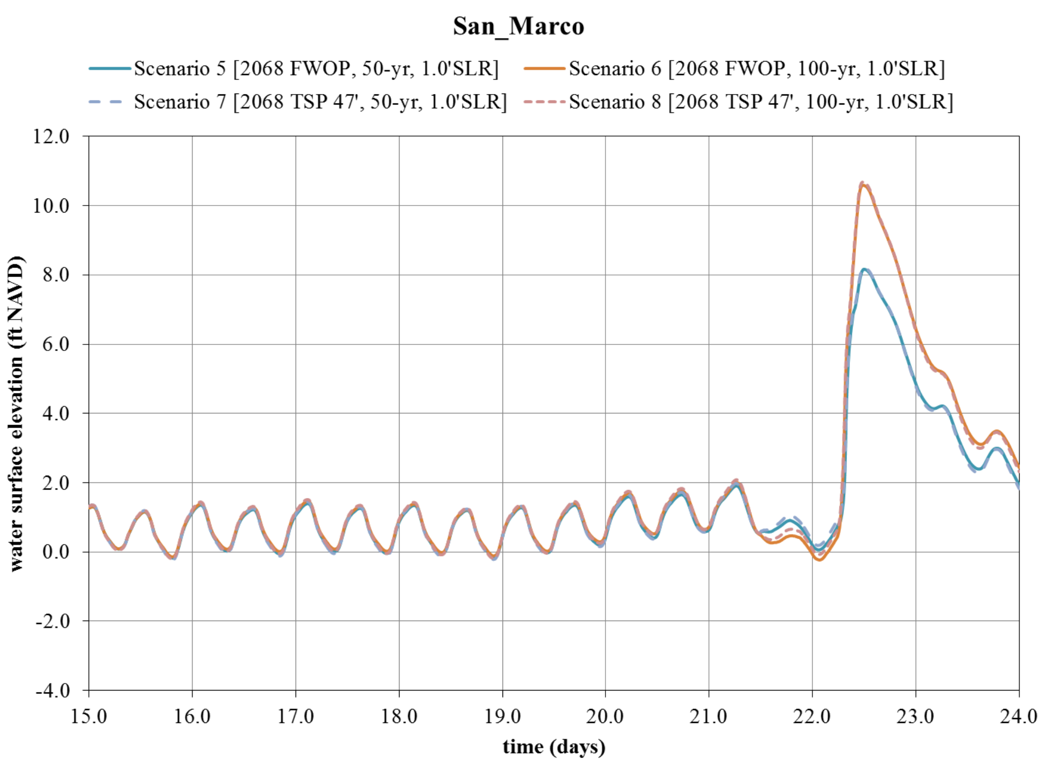

Figure 3.17 Hydrographs for Scenarios 5 – 8; San Marco

Scenario 9 simulates the same storm forcing and channel configuration as Scenarios 1 and 5, but with a 2-ft SLR. As expected, Figure 3.18 shows increased ADCIRC+SWAN water levels for Scenario 9 compared to Scenarios 1 and 5 (Figures 3.1 and 3.10). The figure shows water levels offshore near 11.2 ft-NAVD88 with values in the project area approaching 8.2 ft-NAVD88. Similar to the results of Scenario 5, significant breaching of the barrier island near Jacksonville Beach occurs.

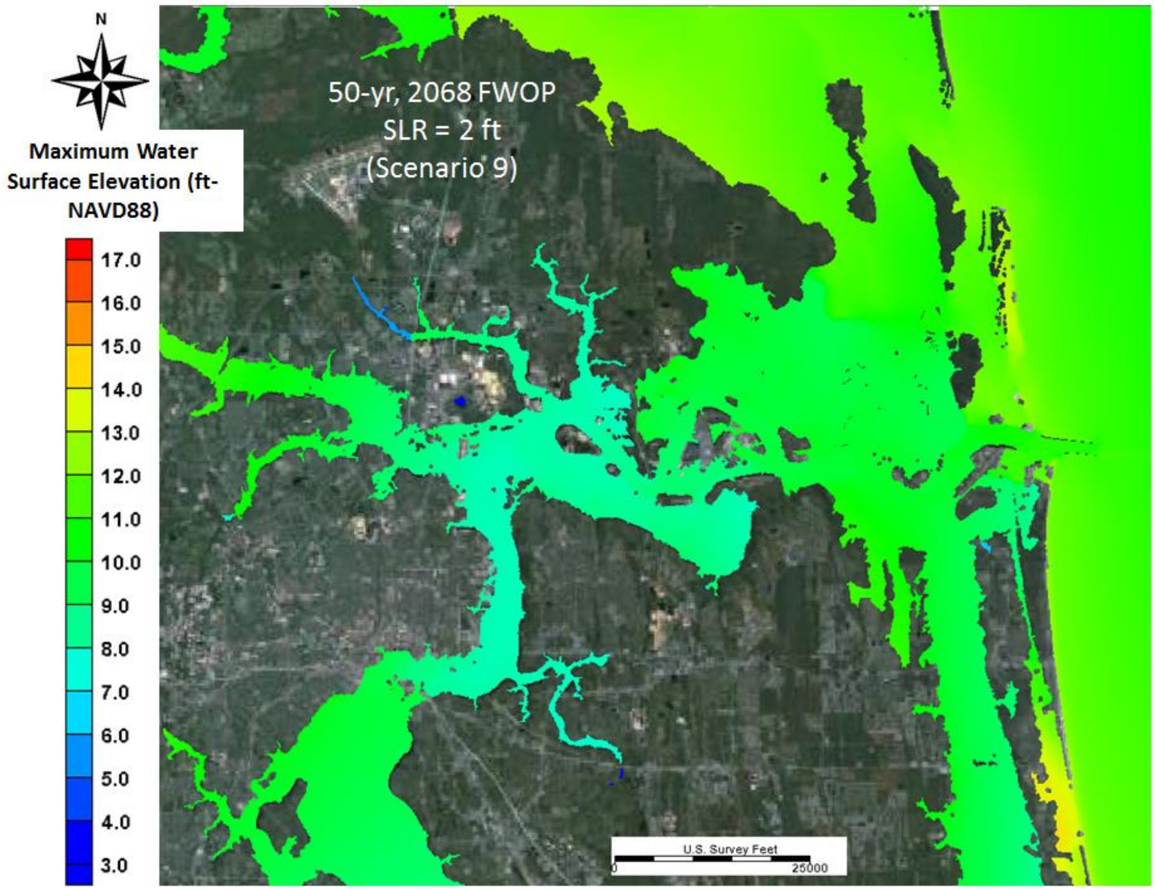

Figure 3.18 Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 9

Scenario 10 applies similar storm forcing and channel configuration as Scenarios 1, 5, and 9, but with a 6 ft SLR. As expected, the ADCIRC+SWAN water levels for Scenario 10 show greatly increased water levels and inundation extents as compared to Scenarios 1, 5, and 9 (Figure 3.19). The figure shows offshore water levels near 14.8 ft-NAVD88 with values in the project vicinity that approach 12.5 ft-NAVD88. Notably, with the exception of the channel configuration changes, the ADCIRC+SWAN mesh represents existing conditions. SLR changes occur slowly and associated significant topography and bathymetry changes would likely during the interval necessary to achieve a 2-ft or 6-ft SLR level.

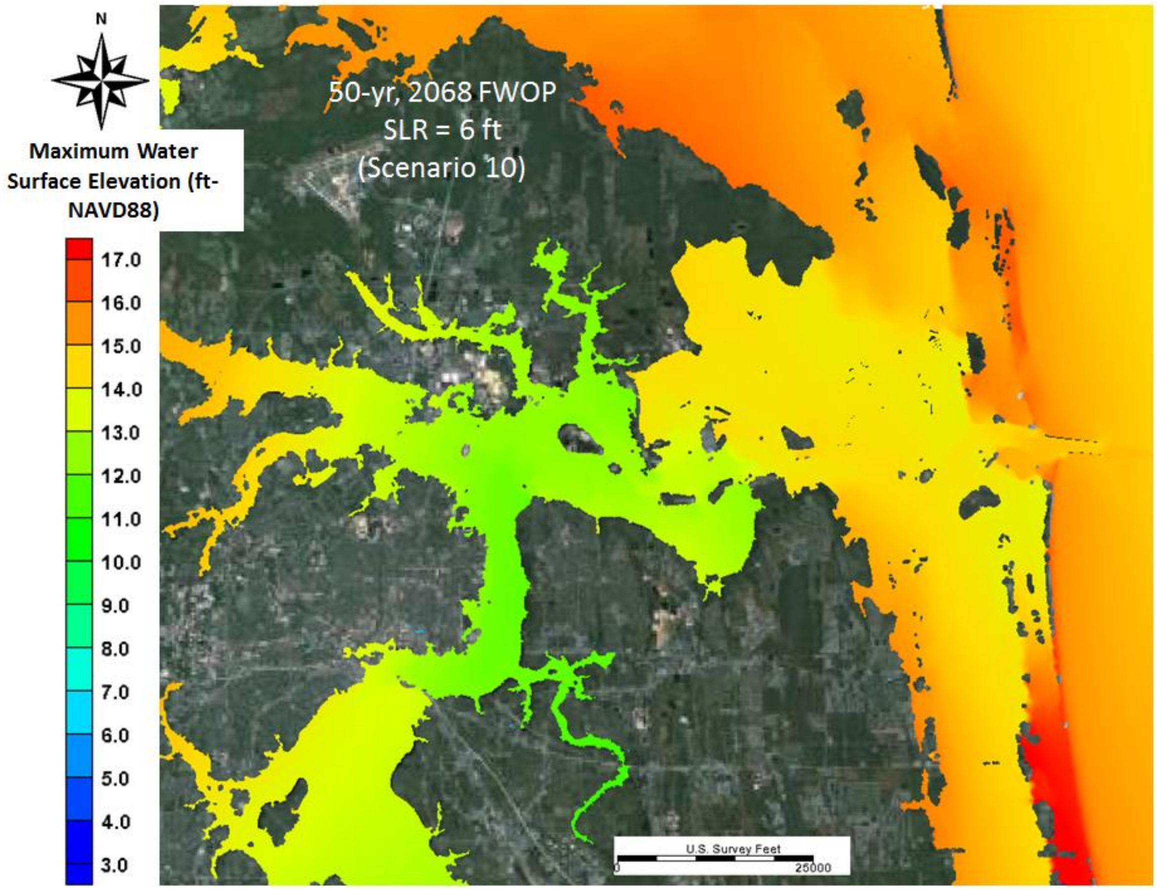

Figure 3.19 Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Scenario 10

Figures 3.20 – 3.23 show water level hydrographs for Scenarios 1, 9, and 10 to demonstrate differences in tide and storm surge levels at specific locations (Figure 3.5). The figures show the change in tide and surge levels at these locations for the three different SLR scenarios applied. The results do not indicate significant non-linearity in the surge response for the different SLR values. Table 3.1 presents the maximum WSE data for the Mayport, Dames Point Bridge, Trout River, and San Marco stations for all 10 scenarios. The table also presents the effect of the channel deepening on maximum WSE and the effect of SLR on the maximum WSE. For the four stations presented, the table shows that the channel deepening has the greatest impact on maximum WSE at the Dames Point Bridge with values near 0.25 ft. The effect of SLR on the maximum WSE shows generally linear response (SLR increase results in similar increase in maximum WSE) for SLR less than 2 ft. For the 6-ft SLR, the data show additional effects.

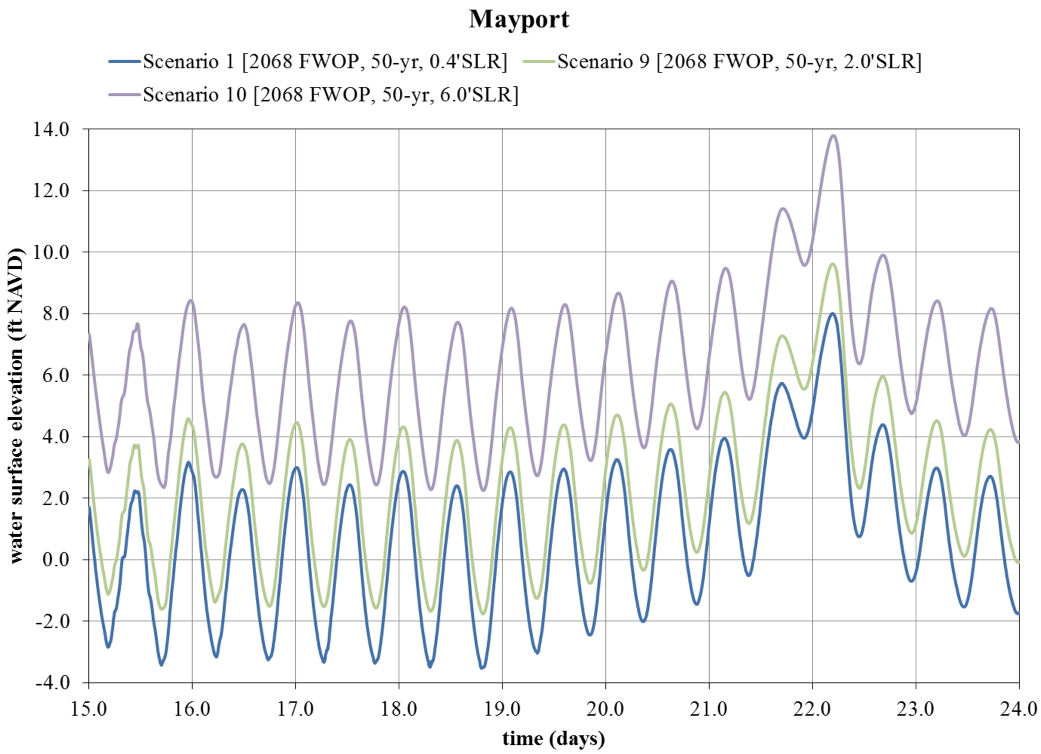

Figure 3.20 Hydrographs for Scenarios 1, 9, and 10; Mayport

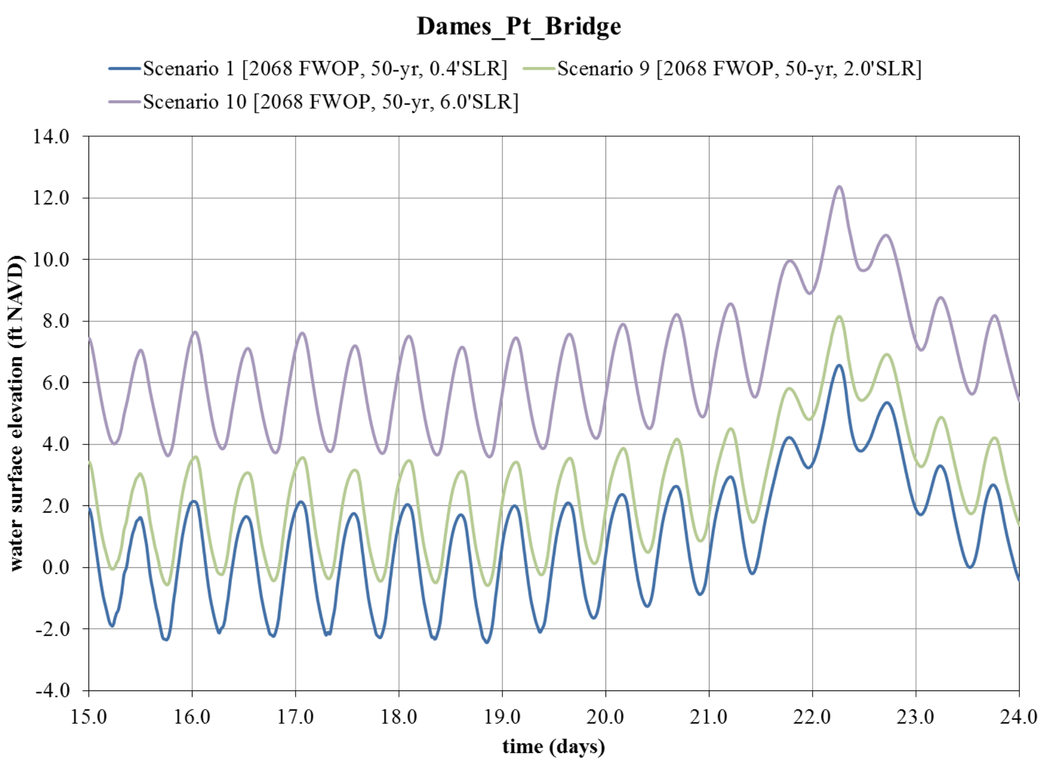

Figure 3.21 Hydrographs for Scenarios 1, 9, and 10; Dames Point Bridge

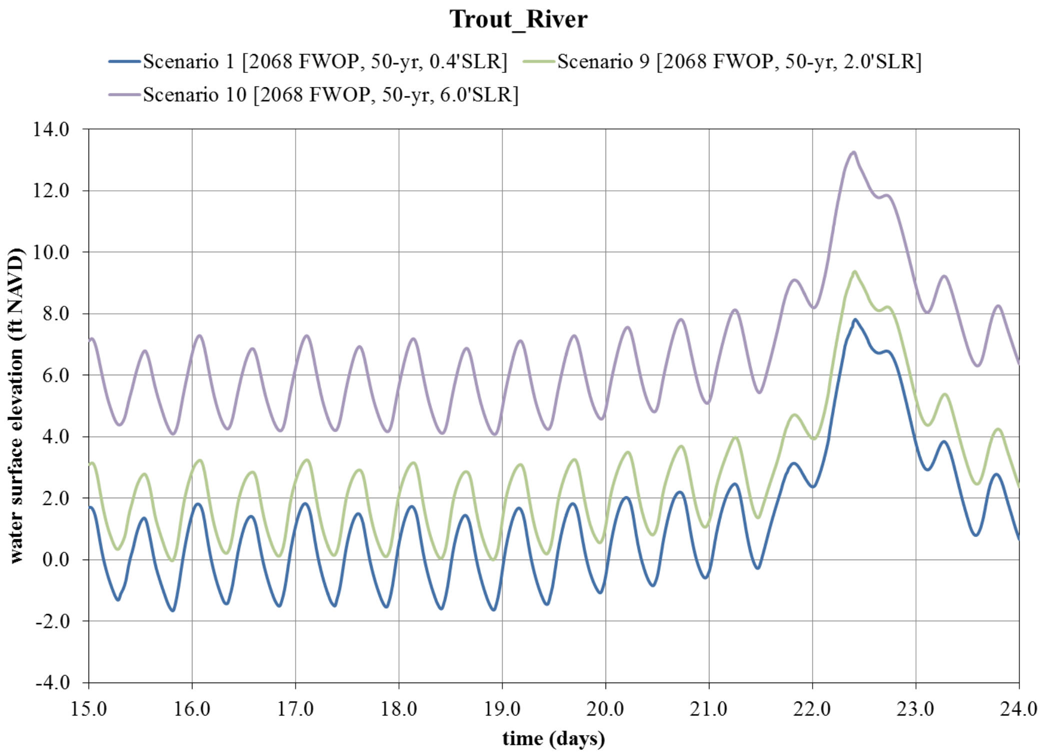

Figure 3.22 Hydrographs for Scenarios 1, 9, and 10; Trout River

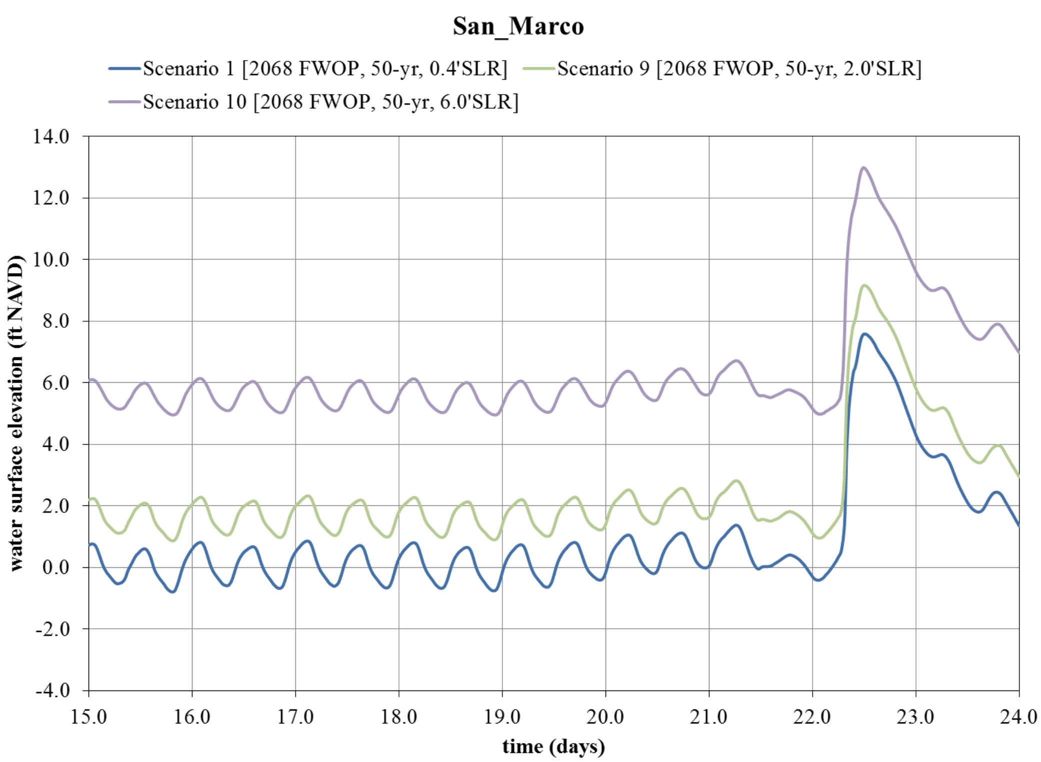

Figure 3.23 Hydrographs for Scenarios 1, 9, and 10; San Marco

Table 3.1 Storm Surge Maximum WSE for Four Stations and Effect of Channel Deepening and SLR

		Mayport	Dames Point Bridge	Trout River	San Marco
		Maximum WSE (ft-NAVD88)			
Scenario Results	Scenario 1 [2068 FWOP, 50-yr, 0.4'SLR]	8.01	6.57	7.82	7.59
	Scenario 2 [2068 FWOP, 100-yr, 0.4'SLR]	10.41	9.04	11.41	10.04
	Scenario 3 [TSP 47', 50-yr, 0.4'SLR]	8.15	6.86	7.90	7.65
	Scenario 4 [TSP 47', 100-yr, 0.4'SLR]	10.53	9.31	11.60	10.12
	Scenario 5 [2068 FWOP, 50-yr, 1.0'SLR]	8.60	7.16	8.40	8.17
	Scenario 6 [2068 FWOP, 100-yr, 1.0'SLR]	11.00	9.61	11.96	10.59
	Scenario 7 [TSP 47', 50-yr, 1.0'SLR]	8.74	7.41	8.47	8.22
	Scenario 8 [TSP 47', 100-yr, 1.0'SLR]	11.10	9.87	12.14	10.68
	Scenario 9 [2068 FWOP, 50-yr, 2.0'SLR]	9.63	8.16	9.38	9.17
	Scenario 10 [2068 FWOP, 50-yr, 6.0'SLR]	13.80	12.38	13.26	12.99
		Change in Maximum WSE (ft)			
Effect of Channel Deepening	Scenario 3 - Scenario 1	0.14	0.29	0.08	0.06
	Scenario 4 - Scenario 2	0.12	0.27	0.18	0.08
	Scenario 7 - Scenario 5	0.13	0.25	0.07	0.06
	Scenario 8 - Scenario 6	0.10	0.26	0.17	0.09
		Change in Maximum WSE - SLR Difference (ft)			
Effect of SLR Change (2068 FWOP)	(Scenario 5 - Scenario 1) - ΔSLR (0.6 ft)	-0.01	-0.01	-0.02	-0.02
	(Scenario 6 - Scenario 2) - ΔSLR (0.6 ft)	-0.01	-0.04	-0.05	-0.05
	(Scenario 9 - Scenario 1) - ΔSLR (1.6 ft)	0.01	-0.01	-0.04	-0.02
	(Scenario 10 - Scenario 1) - ΔSLR (5.6 ft)	0.19	0.21	-0.16	-0.20

4.0 HURRICANE DORA; NO SEA LEVEL RISE SIMULATIONS

Bilskie (2013) completed ADCIRC+SWAN hydrodynamic and spectral wave modeling of for tidal and storm conditions with various Jacksonville Harbor channel depth configurations. Storm simulations conducted by Bilskie included ADCIRC+SWAN simulations of Hurricane Dora (1964) with existing and post-dredging (47-ft channel depth) conditions and no SLR for the Jacksonville Harbor channel. The existing channel configuration applied the Georgia / Northeast Florida FEMA ADCIRC+SWAN mesh with the inlet based St Johns River model inserted as described in Appendices A and B.

Figure 4.1 shows the results of the Hurricane Dora simulation for the existing channel conditions and no SLR. The figure shows maximum WSE near 6.2 ft-NAVD88 in the vicinity of the Dames Point Bridge with significant areas of inundation in the marshes to the north. The inundation levels show similar values to the 50-yr storm forcing where the maximum WSE near the Dames Point Bridge reached 6.5 ft-NAVD88. Figure 4.2 shows the differences in maximum WSE between Hurricane Dora simulation with existing and post-dredging (2068 TSP 47 ft) channel depths. The results show that 2068 TSP 47 ft channel depth produces slightly higher maximum WSE levels in the vicinity of the deepened (47-ft) channel. Similar to the results shown in Table 3.1, at maximum WSE, the no SLR simulations show a difference of about 0.3 ft near the Dames Point Bridge. Differences generally decrease with distance from the deepened channel areas, as expected. As summarized by Bilskie (2013), simulations of Hurricane Dora for existing and post-dredging conditions did not yield differences in peak surge, timing of the peak surge, or inundation area; therefore, peak surge (for storm tracks and characteristics similar to Hurricane Dora) does not show a sensitivity to changes in Jacksonville Harbor channel depth.

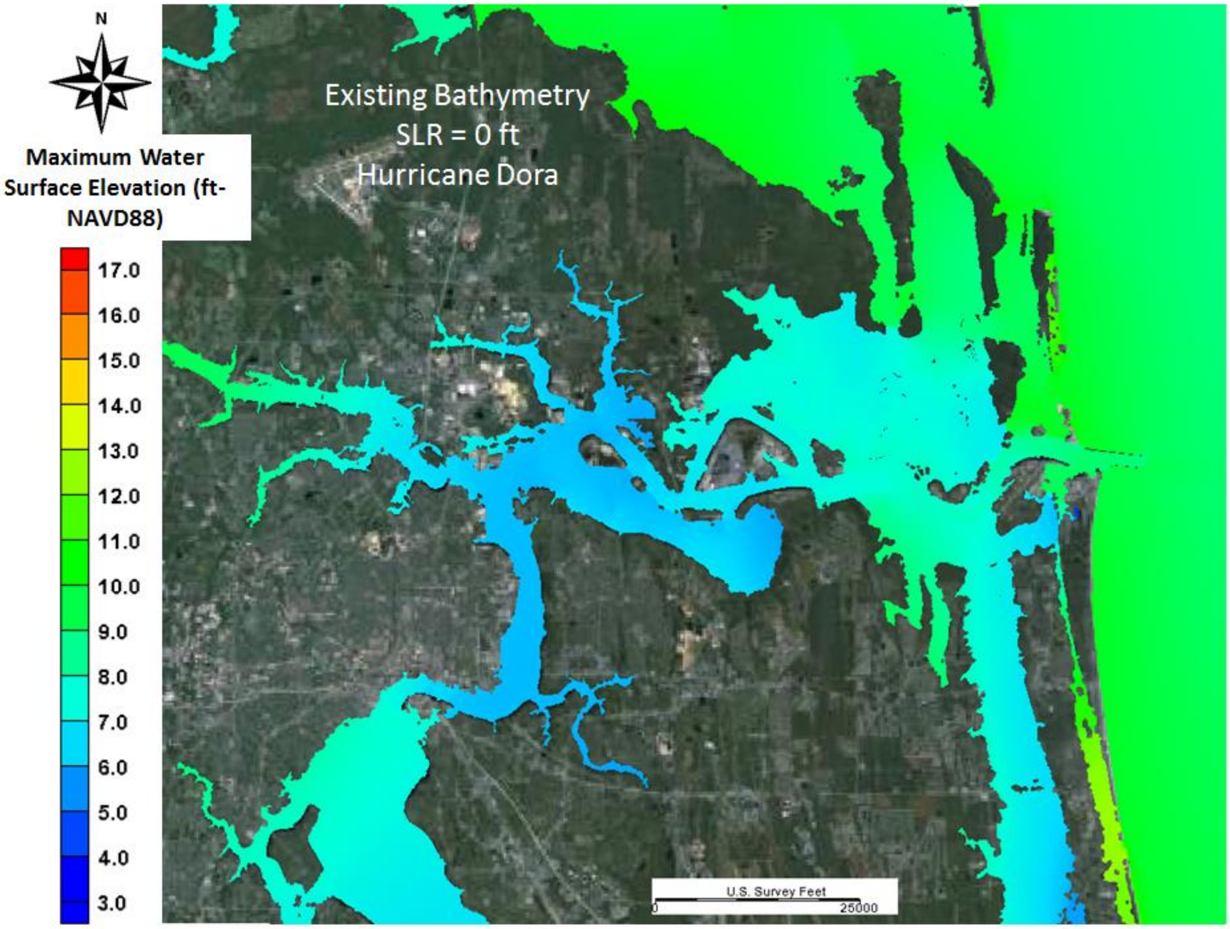

Figure 4.1 Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Hurricane Dora (1964) Simulation with Existing Channel Conditions and No SLR (Bilskie, 2013)

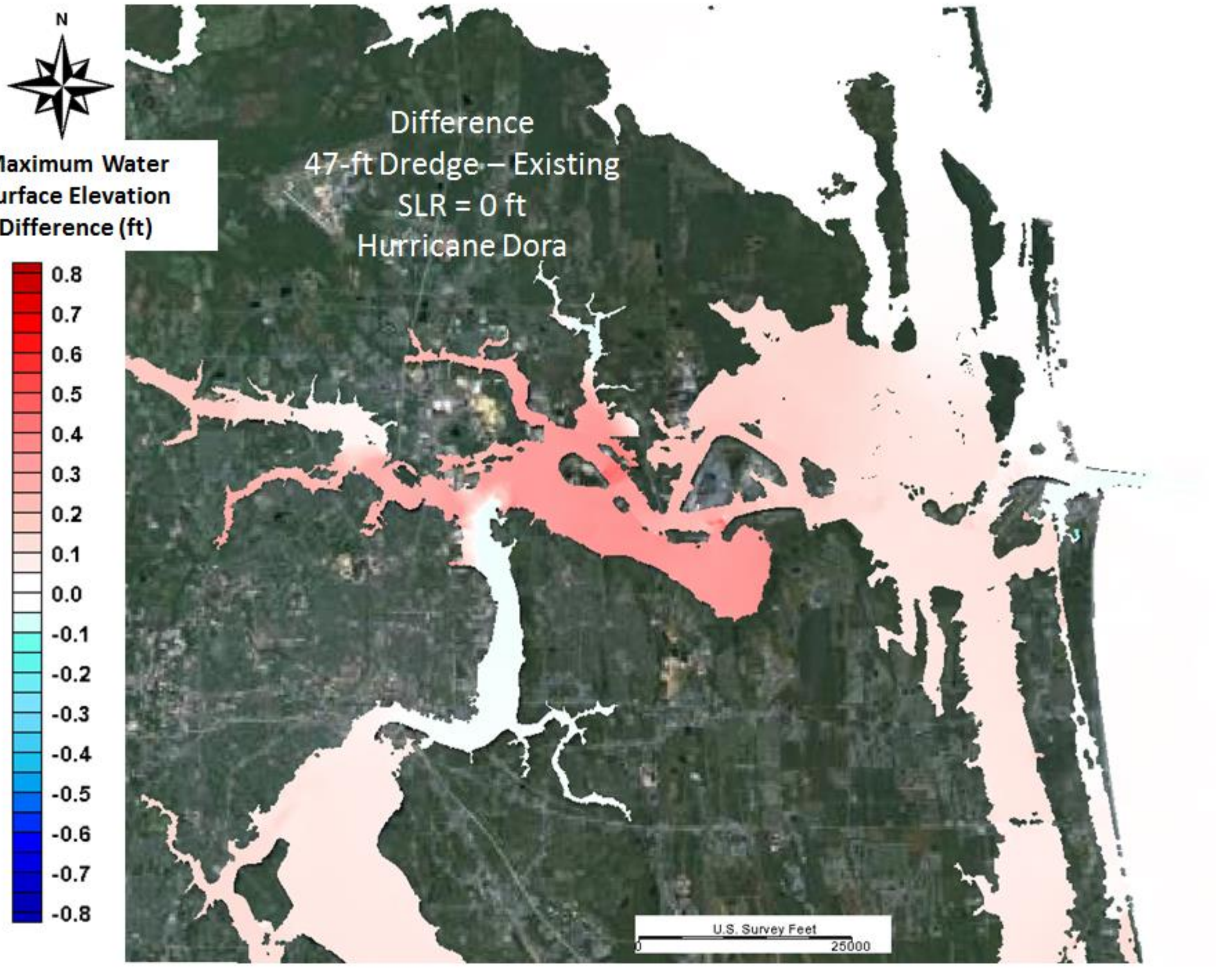

Figure 4.2 Difference in Maximum Water Surface Elevation in Jacksonville Harbor Project Vicinity; Hurricane Dora (1964) Simulation; Existing Channel Minus 2068 TSP 47 ft Configuration (Bilskie, 2013)

5.0 SUMMARY

This report documents the ADCIRC+SWAN modeling for the Jacksonville Harbor Navigation Channel Design. The simulations applied different Jacksonville Harbor channel depth configurations (existing and 47-ft depth), SLR scenarios (0.4, 1, 2, and 6 ft), and synthetic storm forcing (50- and 100-yr storms). The application of various sea level change scenarios in combination with the model forcing and channel configurations allowed evaluation of future scenarios and effects of the tide and storm surge levels. Model results are presented as maximum water levels, water level differences for like forcing but varied channel configuration, and water level time series at specific locations. Examination of these figures allows evaluation of how various channel configurations, storm forcing, and water levels alter the tide and storm surge levels. The model results indicate the 47-ft channel configuration scenario produces only slightly elevated peak water levels as compared to the baseline channel configuration and negligible changes in pre-storm tides. Overall, the model results show more sensitivity to the various SLR scenarios than the channel deepening scenarios. Simulations with no SLR included show similar features with the 47-ft depth channel configuration showing only slightly elevated peak water levels during storm surge events as compared to the existing channel configuration.

6.0 REFERENCES

Bilskie, M.V., (2013) Hydrodynamic Modeling of Tides and Hurricane Storm Surge for Pre- and Post-Dredging Conditions in the Lower St. Johns River, Florida. Ports 2013: In Press

Booij, N., Ris, R. C., and Holthuijsen, L. H. (1999). "A third-generation wave model for coastal regions 1. Model description and validation." Journal of Geophysical Research, 104(C4), 7649-7666.

Dietrich, J.C., Zijlema, M., Westerink, J.J., Holthuijsen, L.H., Dawson, C., Luettich, R.A., Jensen, R., Smith, J.M., Stelling, G.S., and Stone, G.W. 2011. Modeling Hurricane Waves and Storm Surge Using Integrally-Coupled, Scalable Computations. Coastal Engineering, 58, 45-65.

Luettich, R. A., and Westerink, J. J. (2006). "Formulation and Numerical Implementation of the 2D/3D ADCIRC Finite Element Model Version 44.XX." <http://adcirc.org/documentv46/ADCIRC_title_page.html>.

Luettich, R. A., Westerink, J. J., and Scheffner, N. W. (1992). "ADCIRC: An Advanced Three-Dimensional Circulation Model For Shelves, Coasts, and Estuaries, I: Theory and Methodology of ADCIRC-2DDI and ADCIRC-3DL." U.S. Army Corps of Engineers.

Hydrodynamic Modeling for Storm Surge and Sea Level Change:

Jacksonville Harbor Navigation Study

Appendix A: Status Report of Data Assembly Review and ADCIRC Mesh Development

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July 2013

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ADCIRC STORM SURGE MODELING FOR JACKSONVILLE HARBOR NAGIVATION CHANNEL DESIGN

Task Order No. 01, Submission 7.1:

STATUS REPORT OF DATA ASSEMBLY REVIEW AND ADCIRC MESH DEVELOPMENT

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OBJECTIVE

The objective of this project is to refine and adapt the ADCIRC mesh for the St. Johns River intertidal zone developed for salinity modeling (herein referred to as the intertidal mesh) and append it to the Northeast Florida / Georgia FEMA ADCIRC mesh (herein termed the NEFLGA FEMA mesh) to facilitate storm surge modeling for the widening and deepening of the lower St. Johns River navigation channel.

DATA COLLECTION

The ADCIRC model is being developed based on previous efforts between the University of Central Florida's CHAMPS Lab (Coastal Hydroscience Analysis, Modeling & Predictive Simulations) and the United States Army Corps USACE), Jacksonville District, for the local St. Johns River (Bacopoulos & Hagen, 2009a, 2009d, 2009c, 2009b) and a related study (Hagen et al., 2013). The large scale NEFLGA FEMA ADCIRC model is used for areas outside the local St. Johns River (BakerAECOM 2012). Further, other modeling efforts of the St. Johns River have been performed by the CHAMPS Lab (Bacopoulos, 2009; Bacopoulos *et al.*, 2009; Bacopoulos *et al.*, 2011).

Bathymetric data collection and review is outlined in Bacopoulos & Hagen (Bacopoulos & Hagen, 2009a).

Lidar elevations in the salt marsh and overland regions are obtained from BakerAECOM (2012).

Water level and current velocity observations is described in Bacopoulos & Hagen (2009a).

Aerial photography used for the study area is Bing Maps and 2009 orthophography obtained via the St. John's Water Management District for Duval County.

Wind & Pressure Fields for Hurricane Dora (1964) and Hurricane Frances (2004) are obtained from Oceanweather Inc. (OWI) developed specifically for the USACE (Oceanweather, 2012).

MODEL DEVELOPMENT

The intertidal mesh will be inserted into the NEFLGA FEMA mesh for storm surge simulations using the coupled hydrodynamic and nearshore wave model, ADCIRC+SWAN. To properly simulate long wave processes from the deep ocean to the local St. John's River as well as incorporate nearshore wave processes, a large scale modeling approach is taken. The NEFLGA FEMA mesh spans the western North Atlantic Ocean from the 60° west meridian (Figure 1). Of the two meshes, the intertidal takes precedence as it best represents the St. Johns River locally, and provides continuity from the salinity modeling effort. Therefore, a transition zone is developed between the two meshes to facilitate appropriate local mesh element size transition. Also, some adjustment must be made to the intertidal mesh to ensure proper element size for both element size transition and simulated wave mechanics (Figure 2).

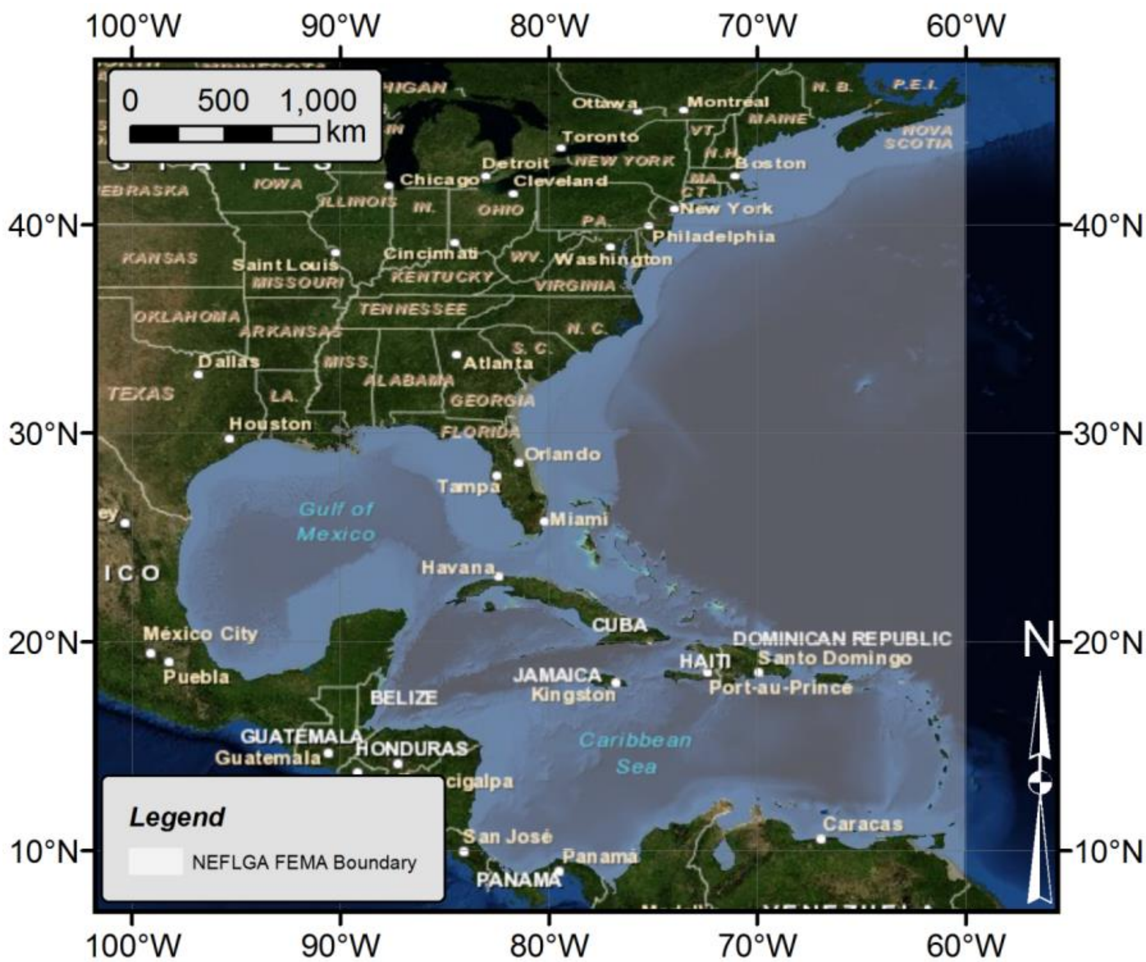

Figure 1 – Large scale NEFLGA FEMA mesh boundary extending to the 60° west meridian

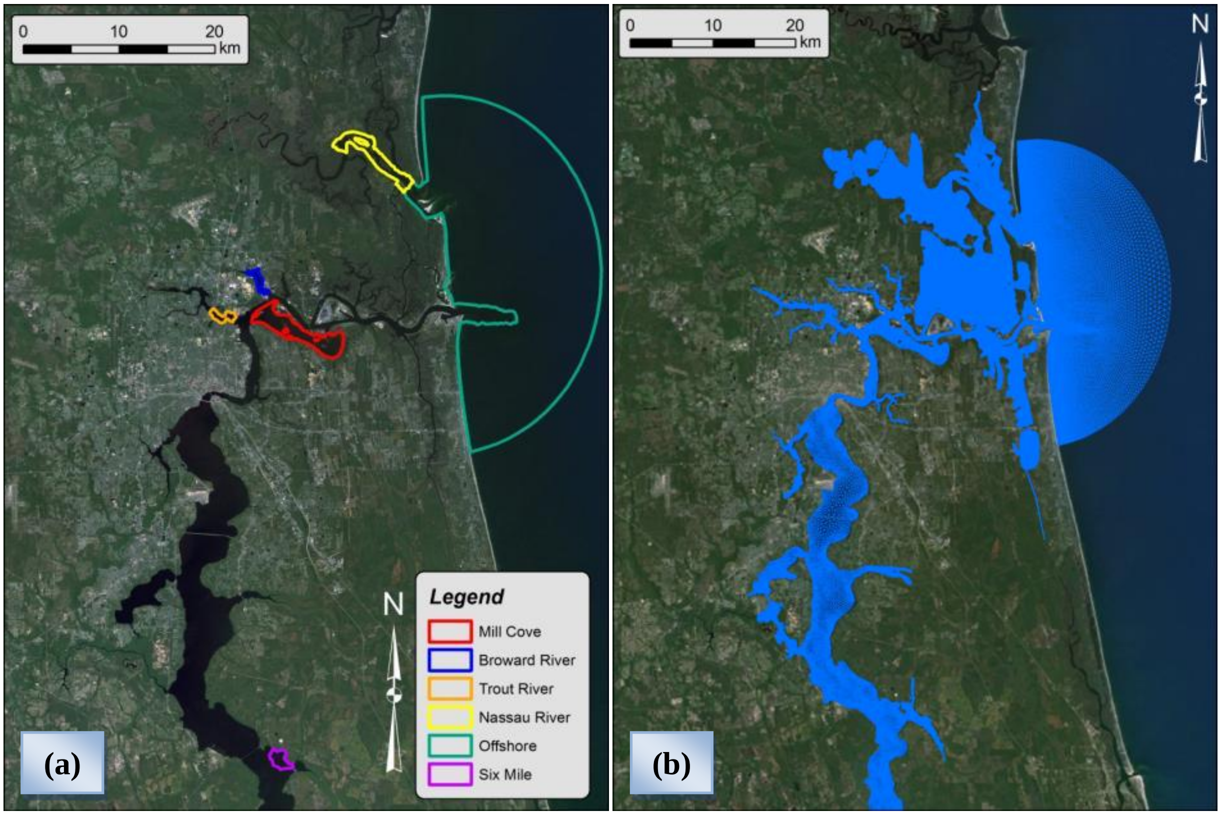

Figure 2 – (a) Six refinement areas to ensure proper mesh transitioning and wave results (b) local St. John's River intertidal mesh

Further, the original intertidal mesh was refined in six areas: offshore (Figure 3), Nassau River (Figure 4), Mill Cove (Figure 5), Broward River (Figure 6), Trout River (Figure 7), and Six Mile (Figure 8). These areas were refined to provide proper element area transition between the intertidal zone mesh and the NEFLGA mesh, necessary mesh resolution for the wave modeling (offshore region), and proper element transition near thin peninsulas (see Figure 8 for an example). Elevations in the refinement areas were obtained from the original intertidal mesh.

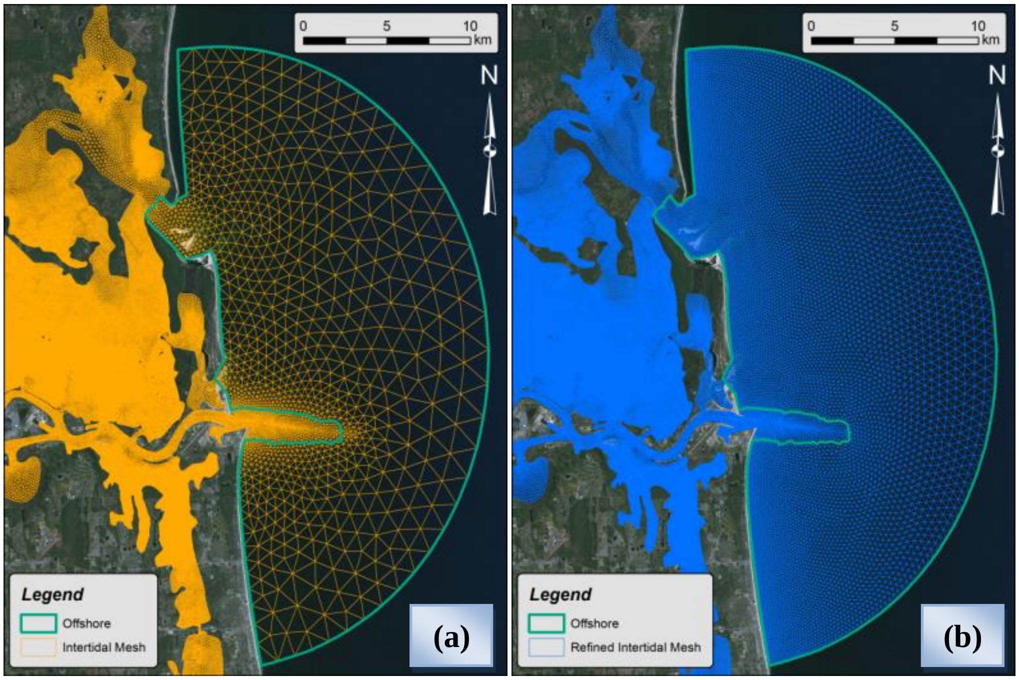

Figure 3 – Offshore (a) original intertidal mesh (b) refined intertidal mesh

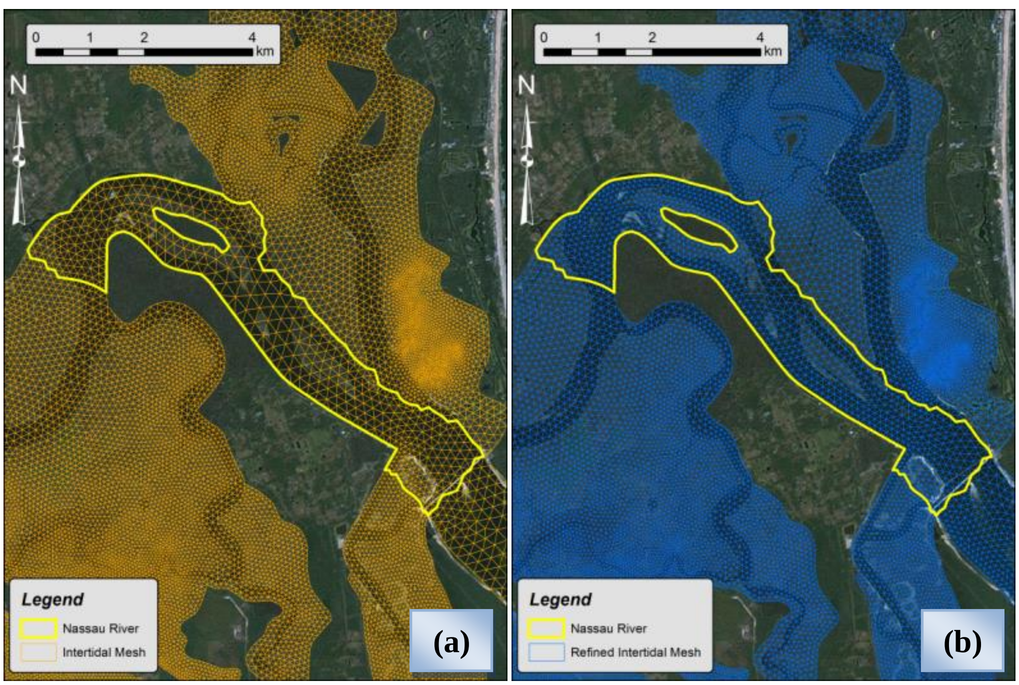

Figure 4 – Nassau River (a) original intertidal mesh (b) refined intertidal mesh

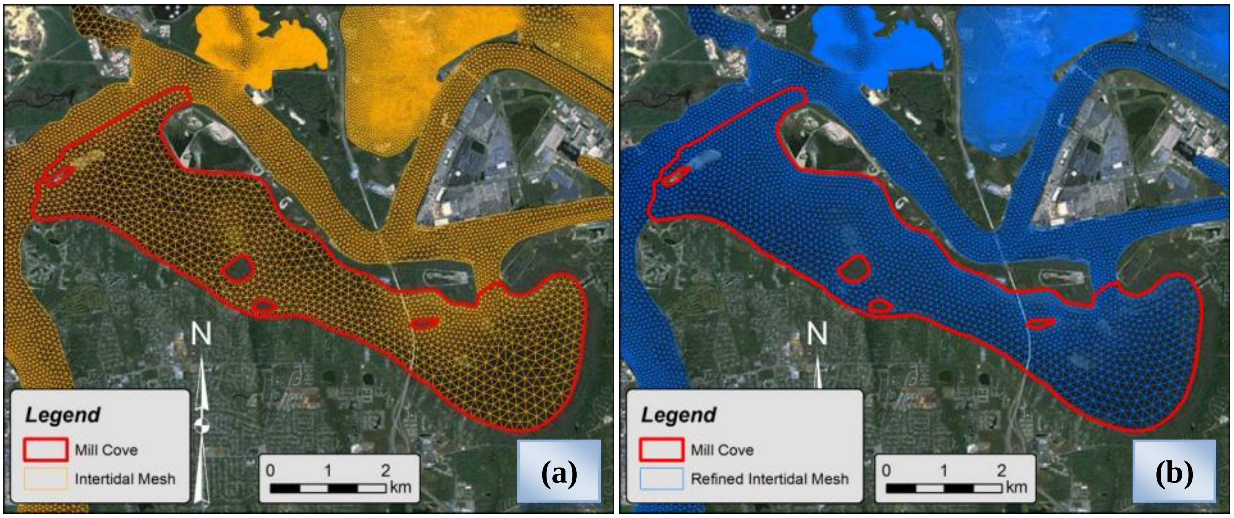

Figure 5 – Mill Cove (a) original intertidal mesh (b) refined intertidal mesh

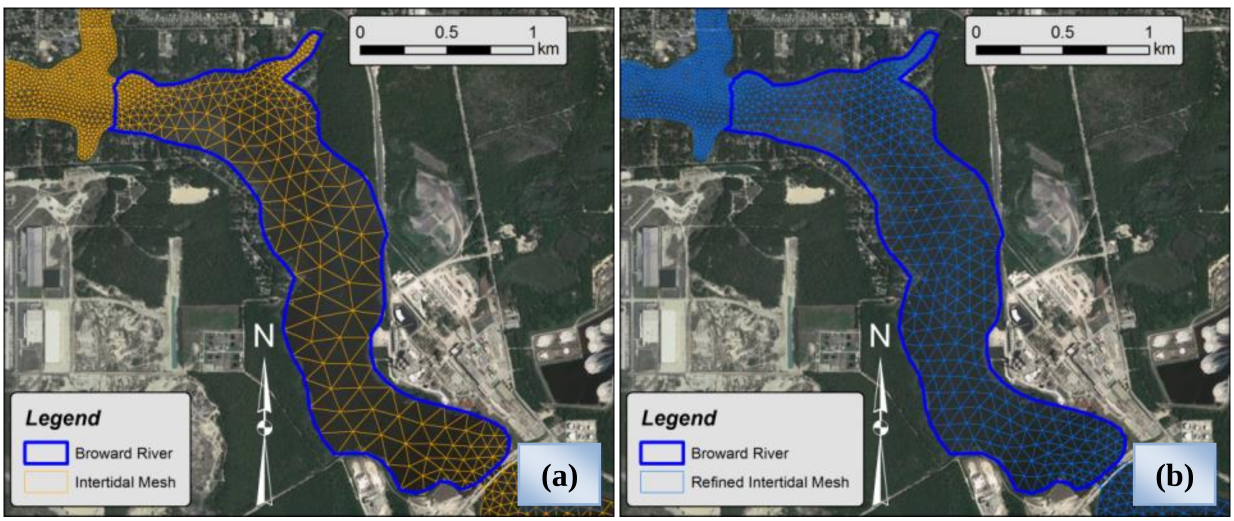

Figure 6 – Broward River (a) original intertidal mesh (b) refined intertidal mesh

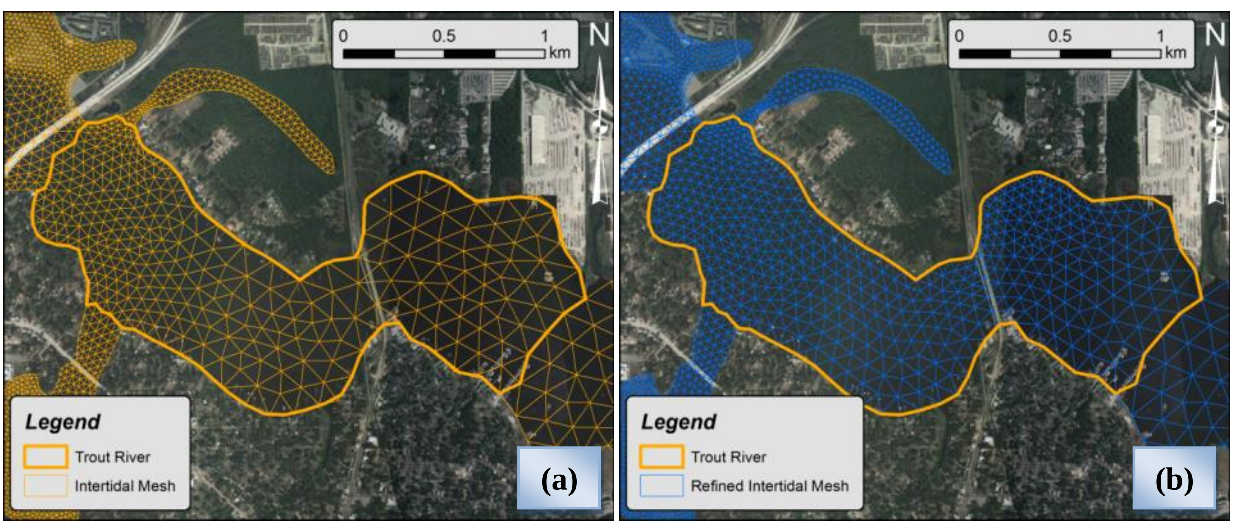

Figure 7 – Trout River (a) original intertidal mesh (b) refined intertidal mesh

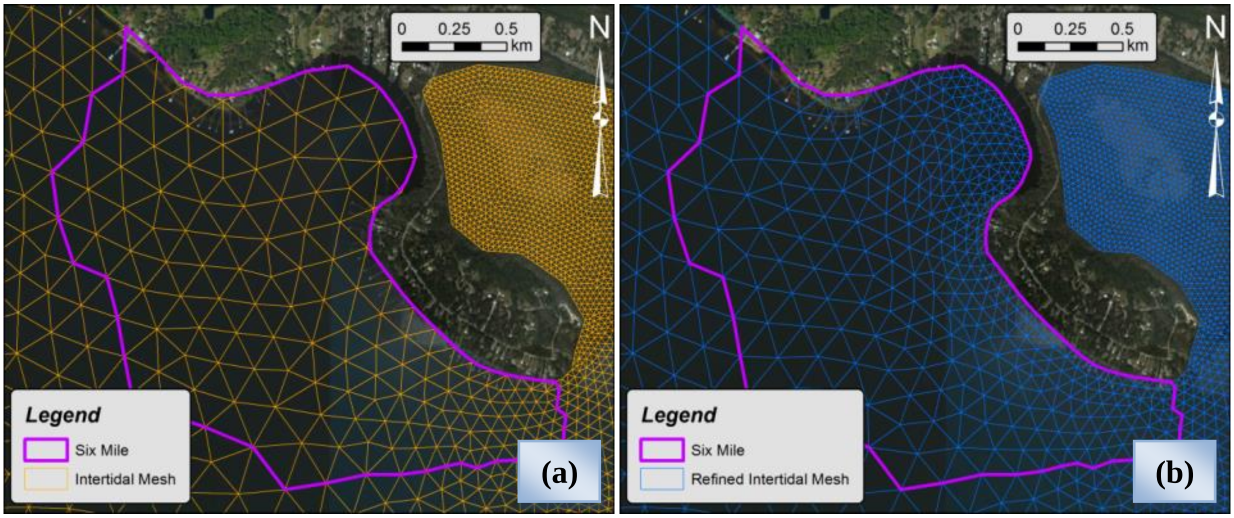

Figure 8 – Six Mile (a) original intertidal mesh (b) refined intertidal mesh

A seamless transition between the NEFLGA FEMA mesh and refined intertidal mesh in terms of local element area size is crucial (Figure 9). Numerical instabilities may arise if the element size ratio of neighboring elements is too large. To this end, a transition (or buffer) zone is developed. For example, a 300 m buffer is used south of the St. John's River inlet along the marsh to the west and Atlantic Ocean shoreline to the east (Figure 10 and Figure 11). This methodology is continued until the intertidal mesh is fully integrated into the NEFLGA FEMA mesh. The end product will be used by the University of Central Florida to simulate storm surge for pre- and post-dredging conditions.

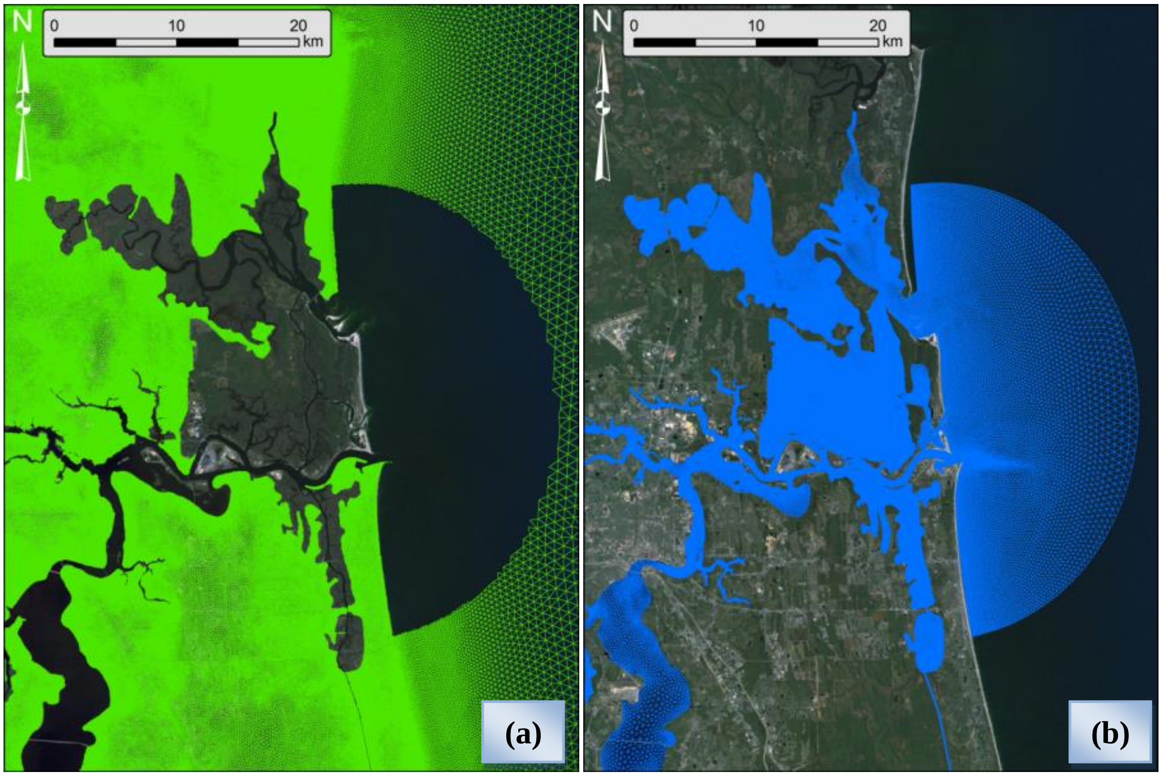

Figure 9 (a) – NEFLGA FEMA mesh with elements removed inside the refined intertidal mesh boundary (b) – Refined intertidal zone mesh

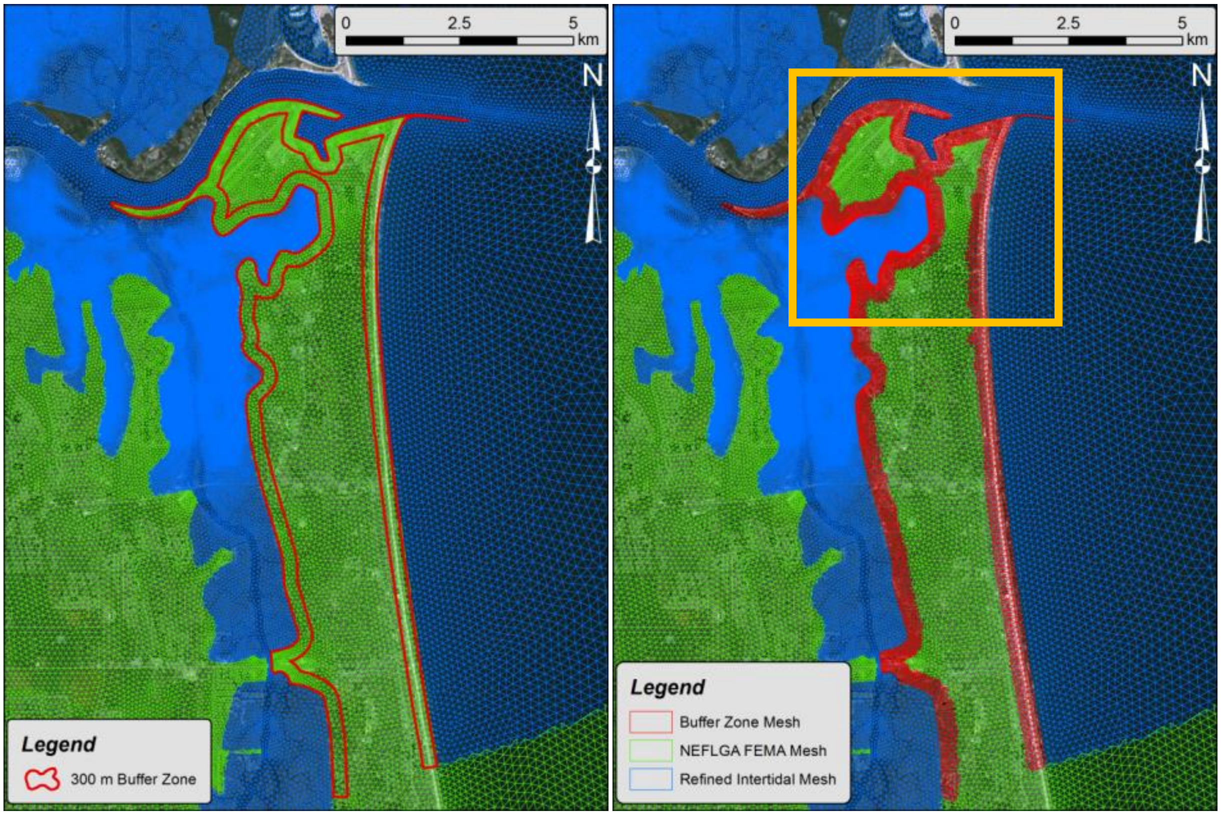

Figure 10 - NEFLGA FEMA Mesh (green) and refined intertidal mesh (blue) (a) 300 m buffer (transition) zone and (b) elements removed within the buffer zone

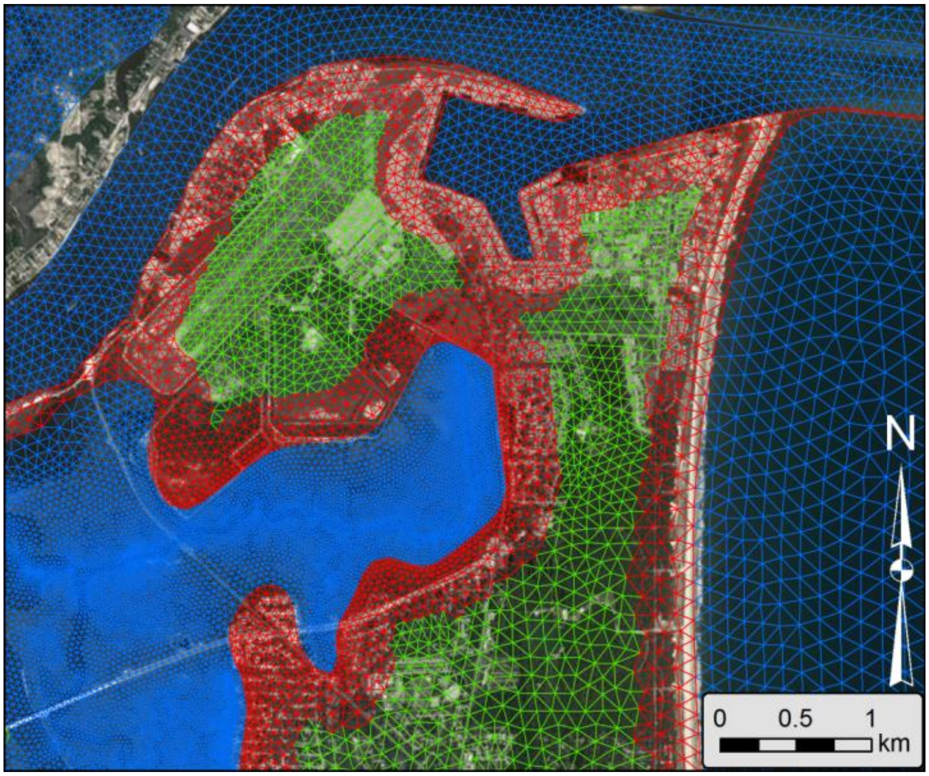

Figure 11 – Zoom in on Figure 10b

REFERENCES

Bacopoulos, P. (2009). *Estuarine Influence on Tidally Driver Circulation in the South Atlantic Bight.* Ph.D., University of Central Florida, Orlando, FL.

Bacopoulos, P., Funakoshi, Y., Hagen, S. C., Cox, A. T., & Cardone, V. J. (2009). The role of meteorological forcing on the St. Johns River (Northeastern Florida). *Journal of Hydrology, 369*, 55-70.

Bacopoulos, P., & Hagen, S. C. (2009a). Data Assembly and Review Report *ADCIRC Boundary Conditions for Jacksonville Harbor Navigation Channel Design Modeling (RMA), Salinity Modeling (EFDC), and Coastal Modeling (CMS) at the St. Johns River Entrance* (pp. 17). Orlando, FL: University of Central Florida.

Bacopoulos, P., & Hagen, S. C. (2009b). Final Report of ADCIRC (Hydrodynamic) Modeling In The St. Johns River and Surrounding Marshes *ADCIRC Boundary Conditions for Jacksonville Harbor Navigation Channel Design Modeling (RMA), Salinity Modeling (EFDC), and Coastal Modeling (CMS) at the St. Johns River Entrance* (pp. 123). Orlando, FL: University of Central Florida.

Bacopoulos, P., & Hagen, S. C. (2009c). Final Tidal Boundary Conditions, Including Updates for Fort George River & Inlet *ADCIRC Boundary Conditions for Jacksonville Harbor Navigation Channel Design Modeling (RMA), Salinity Modeling (EFDC), and Coastal Modeling (CMS) at the St. Johns River Entrance* (pp. 24). Orlando, FL: University of Cental Florida.

Bacopoulos, P., & Hagen, S. C. (2009d). Summary of Calibration and Validation Results & Required Boundary Conditions Input Files *ADCIRC Boundary Conditions for Jacksonville Harbor Navigation Channel Design Modeling (RMA), Salinity Modeling (EFDC), and Coastal Modeling (CMS) at the St. Johns River Entrance* Orlando, FL: University of Central Florida.

Bacopoulos, P., Parrish, D. M., & Hagen, S. C. (2011). Unstructured mesh assessment for tidal model of the South Atlantic Bight and its estuaries. *Journal of Hydraulic Engineering, Special Issue on Coastal Maritime Hydraulics, 49*(4), 487-502.

BakerAECOM 2012 Technical Approach, Topographic/Hydrographic Digital Elevation Model (submitted to Federal Emergency Management Agency)

Hagen, S.C., J.T. Morris, P. Bacopoulos*, and J. Weishampel, “Sea-Level Rise Impact on a Salt Marsh System of the Lower St. Johns River.” ASCE *Journal of Waterway, Port, Coastal, and Ocean Engineering*, To Appear, March/April 2013.

Oceanweather. (2012). Commerical Proposal and License Agreement Hurricane Dora (1964) and Hurricane Frances (2004) Tropical Winds and Pressures (pp. 10). Cos Cob, CT.

Hydrodynamic Modeling for Storm Surge and Sea Level Change:
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Appendix B: Status Report of ADCIRC Mesh Development

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ADCIRC STORM SURGE MODELING FOR
JACKSONVILLE HARBOR NAGIVATION CHANNEL DESIGN

Task Order No. 01, Submission 7.2:

STATUS REPORT OF ADCIRC MESH DEVELOPMENT

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The objective of this project is to refine and adapt the ADCIRC mesh for the St. Johns River in nine priority areas and merge to the Northeast Florida / Georgia FEMA ADCIRC model (herein termed the NEFLGA FEMA mesh) to facilitate storm surge modeling for the deepening of the Lower St. Johns River. In effect, these nine priority areas (Figure 1) must be updated to include higher resolution in the channels and adjacent floodplain. Also, modifications must be made to the topography and bathymetry of the ADCIRC mesh in order to provide adequate volumetric flow capacity, a key aspect of storm surge modeling.

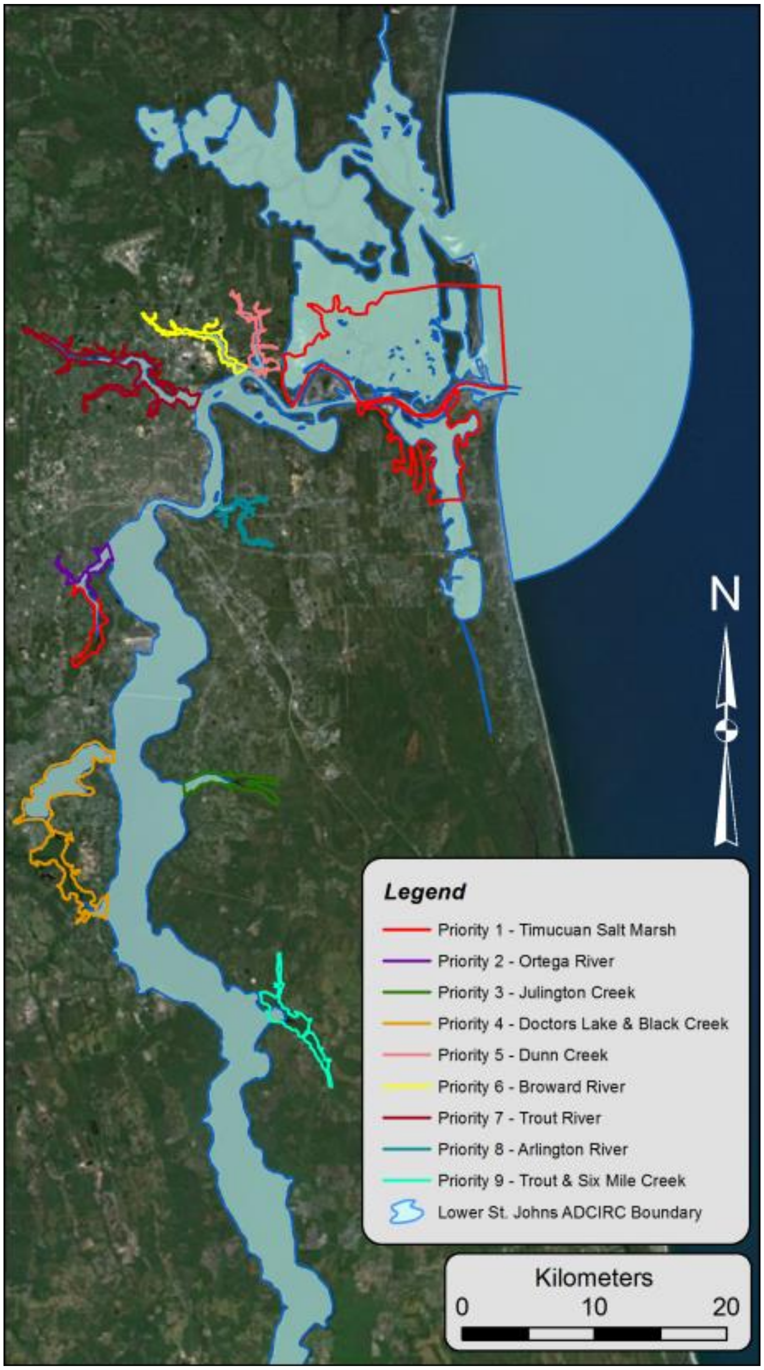

Figure 1 – Lower St. Johns River priority areas.

First, model resolution was increased in the nine priority areas to as low as 15 to 20 meters where required in order to provide adequate elemental coverage across the channel as well as coverage in the marsh/floodplain. Also, high mesh resolution is required in the adjacent low lying floodplain to resolve the tidal creeks and simulate the daily flooding and drying of the marsh table. Previous research has indicated that a minimum of three elements across the channel (i.e. trapezoidal channel) and the dissipation of energy in the marsh system are necessary to simulate flow conditions and permit realistic volumetric transfer. This volumetric transfer is crucial to storm surge modeling. An example of this mesh refinement is shown in below in Figure 2.

Figure 2 – Priority area three (Julington Creek) (a) before refinement (b) after refinement.

The new refined mesh was tested using a 45-day tide simulation. The model with refinements in the nine priority areas was simulated by imposing a harmonic constituent forcing at the semi-circular open ocean boundary and north and south Intracoastal Waterway (ICWW) boundaries. The model appears to be producing reasonable, stable results in terms of water levels (Figure 3). A secondary test is to examine the maximum water elevation plot (Figure 4). This shows the elevation of the maximum water level occurring during the simulation at each node. As shown in Figures 4 and 5, there are no apparent anomalous water levels. Therefore, the refined mesh is functional and able to proceed to the next step in the project, validation.

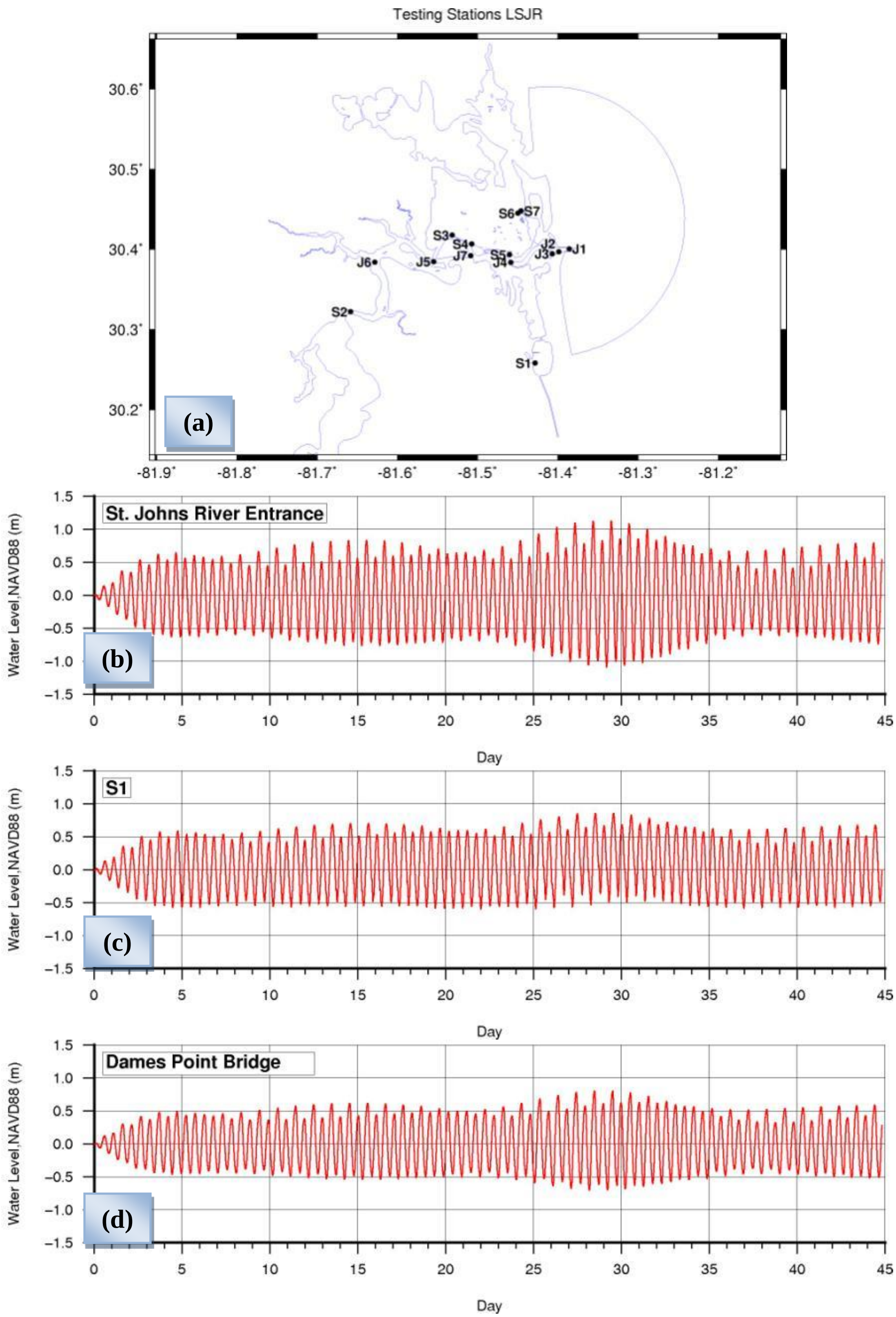

Figure 3 - (a) Location of test locations and selected stations tide signals at (b) St. Johns River entrance, (c) south ICWW, and (d) Dames Point Bridge.

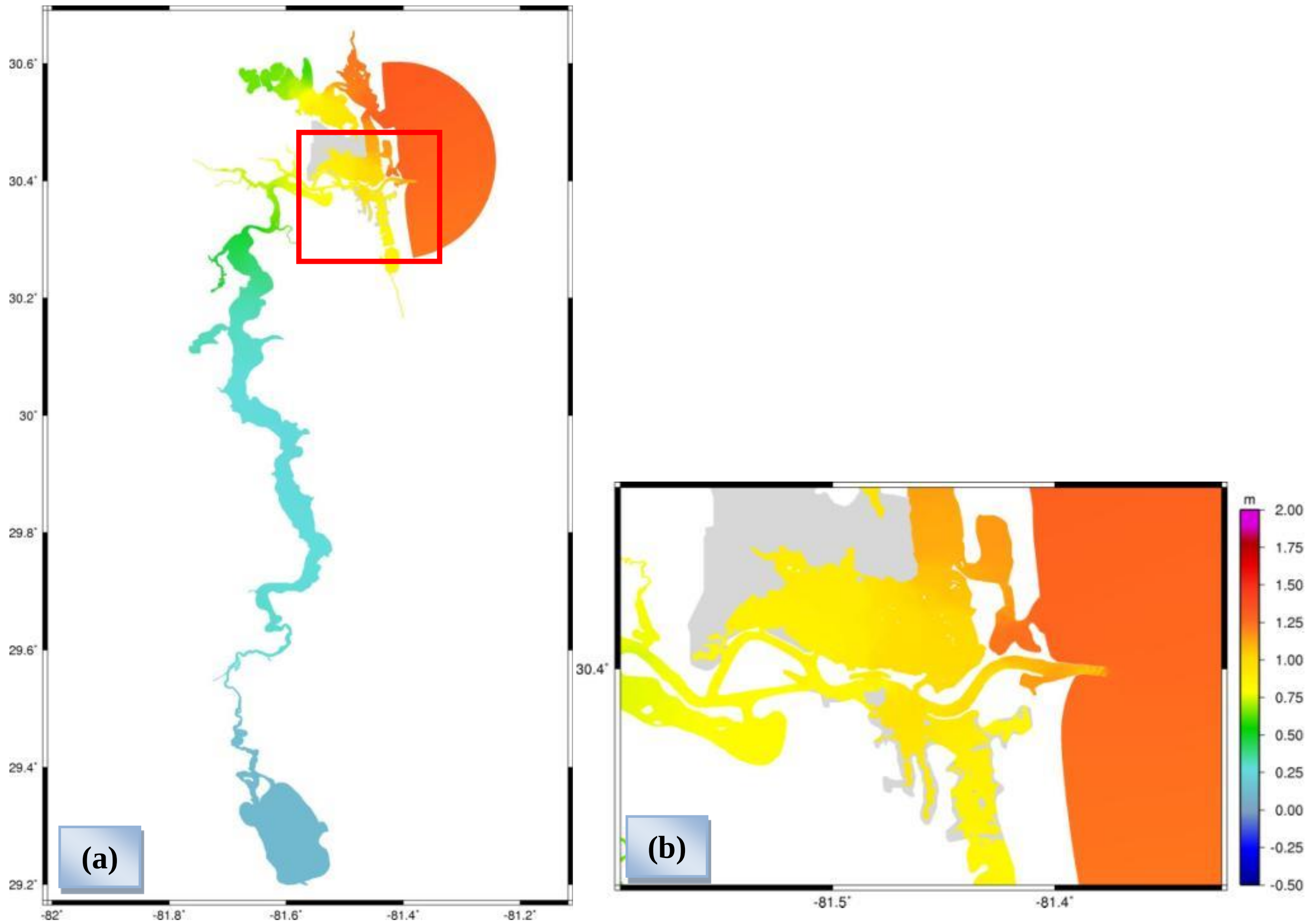

Figure 4 - Maximum water surface elevations from a 45-day tidal simulation: (a) for the entire lower St. Johns River; and, (b) for the Jacksonville region, see inset (a).

The refined St. Johns River mesh (Figure 5a and c) will be integrated with the NEFLGA FEMA mesh (Figure 5b and d). This will be accomplished by gradually transitioning the mesh resolution outward from the refined mesh until is seamlessly matches that of the NEFLGA FEMA mesh. Therefore, the mesh resolution of the NEFLGA FEMA mesh will increase in this transition zone. The resultant mesh will include high resolution of the main river channel, marsh systems and tidal creeks and surrounding floodplain. The end product will be used by the University of Central Florida (UCF) to simulate storm surge for pre- and post-dredging conditions.

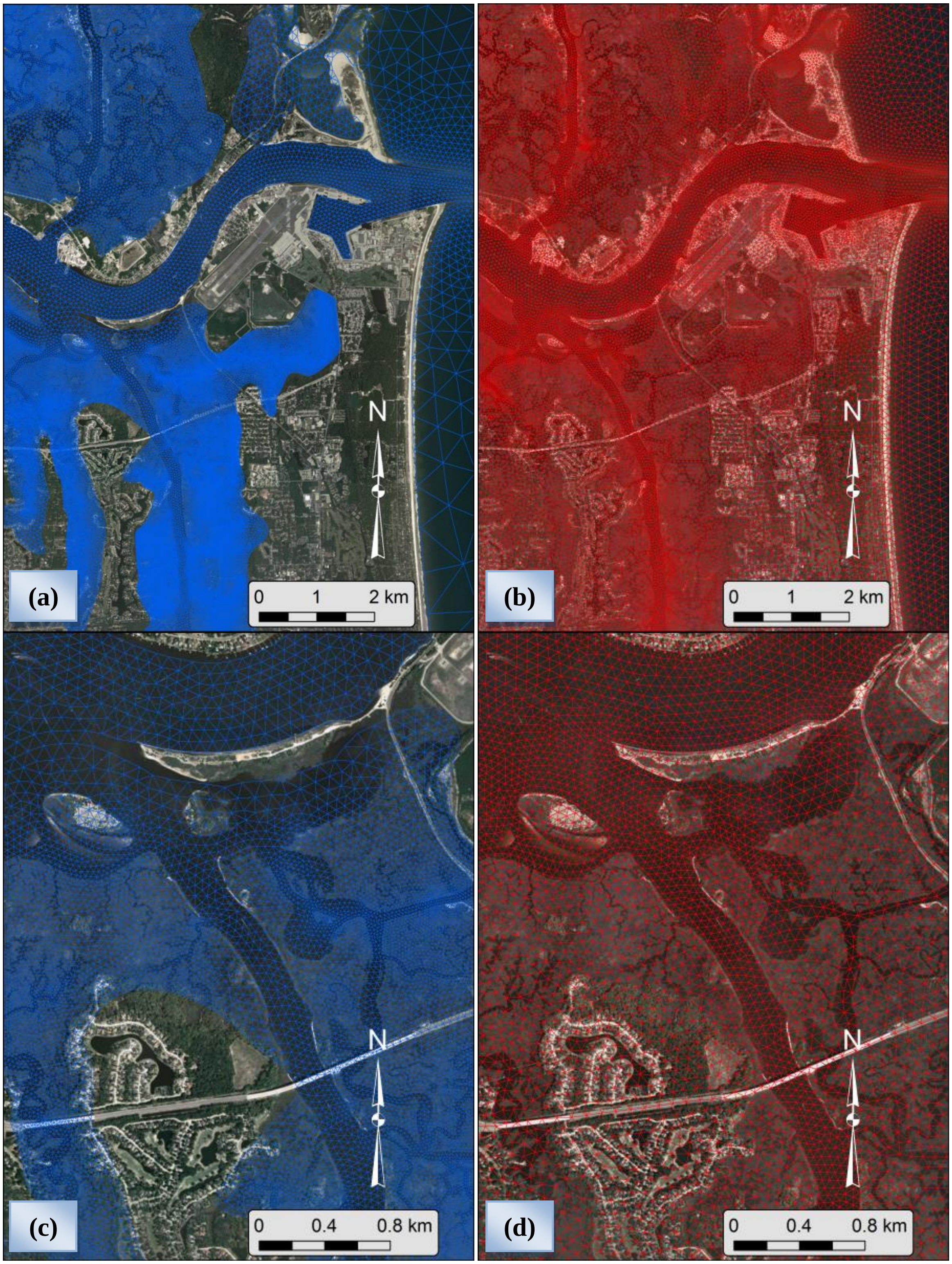

Figure 5 – St. Johns River Inlet: (a) refined St. Johns River mesh (b) NEFLGA FEMA mesh; and, zoom in south of the main channel: (c) refined St. Johns River mesh (d) NEFLGA FEMA mesh.

Hydrodynamic Modeling for Storm Surge and Sea Level Change:

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Appendix C: Storm Selection for ADCIRC+SWAN Model Calibration and Validation

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Storm Selection for ADCIRC+SWAN Model Calibration and Validation

Final Report

Prepared for

U.S. Army Corps of Engineers; Jacksonville District

by

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March 2013 (Revised Sept 2013)

C2012-054

Introduction

The ADCIRC+SWAN Storm Event Modeling for Jacksonville Harbor Navigation Channel Design study requires application of water level data from two different storms to calibrate and verify the ADCIRC + SWAN model. Because the study seeks to examine water levels during extreme events, ideal storms to calibrate and verify the model are those that caused the highest observed storm surges in the project area and had accurate measured data at multiple locations along the river.

To select the appropriate storms, this study relies on an ongoing Taylor Engineering / Baker AECOM Georgia and Northeast Florida storm surge study (GANEFLSSS) for the Federal Emergency Management Agency (FEMA). Given that the domain of interest in this study is a subset of the GANEFLSSS domain, historical storm information and analysis presented in GANEFLSSS is directly relevant to the current project.

Candidate Storms

The GANEFLSSS investigated peak storm surge magnitude, storm track, and water level and wave data availability to identify five storms (Figure 1) as candidates for validation of its ADCIRC+SWAN model. The same five storms (Table 1) form the suite of candidate storms for model calibration/validation in the present study. Figures 3 and 4 present locations of National Oceanic and Atmospheric Administration (NOAA) stations with measured data during the candidate storms. Notably, though Hurricane Jeanne (landfall at Stuart on 9/25/04 as a Category 3 storm) caused a higher storm surge than Hurricane Frances, this list excludes the storm because the water levels during Jeanne were influenced by the remnants of Hurricane Ivan, which passed by the area on 9/20/04 and caused a "pre-surge" of the water level. Figure 4 presents an example of this behavior at Mayport Naval Station. Because fully modeling the effect of Hurricane Jeanne would require additional modeling of Ivan's wind field, the validation storm suite excludes Hurricane Jeanne.

Table 1 Characteristics of Candidate Storms for Model Calibration/Validation

Storm Name	Dates	Max Category	Landfall Location	Max Storm Surge* ft	Number of NOAA stations with water level data**
Dora	8/28/64 – 9/16/64	H3	St. Augustine, FL	5.91	3
David	8/25/79 – 9/8/79	H2	North-Central GA	5.55	5
Frances	8/25/04 – 9/10/04	H2	Stuart, FL	3.85	15
Tammy	10/5/05 – 10/7/05	TS	Atlantic Beach, FL	4.07	9
Fay	8/15/08 – 8/28/08	TS	Daytona Beach, FL	3.99	6

*Recorded by NOAA gage

** Figures 2 and 3 show the locations of all relevant NOAA stations

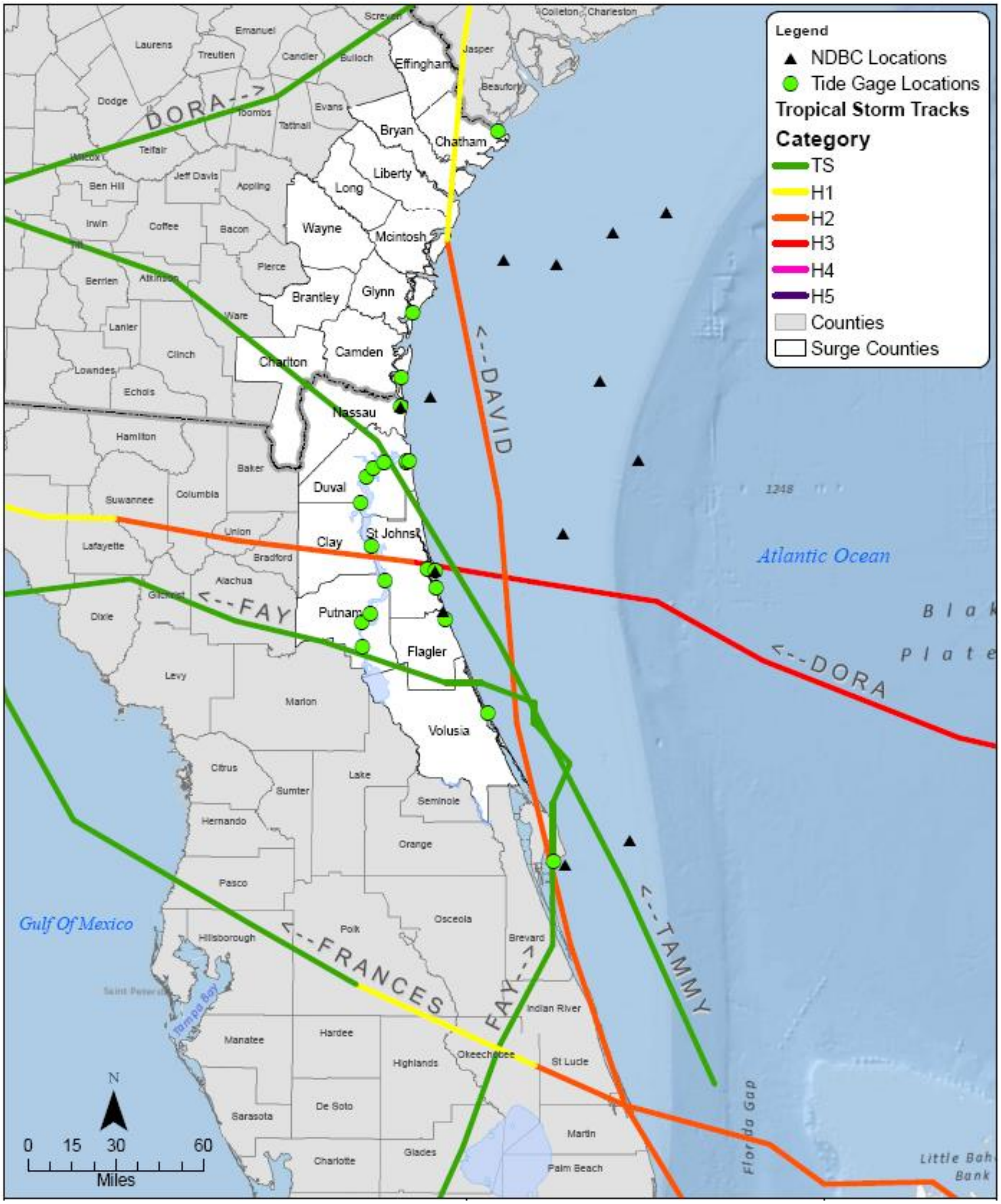

Figure 1 Tracks of Storms Selected for Model Validation in GANEFLSSS and Locations of Wave and Tide Gage Stations (BakerAECOM, 2012)

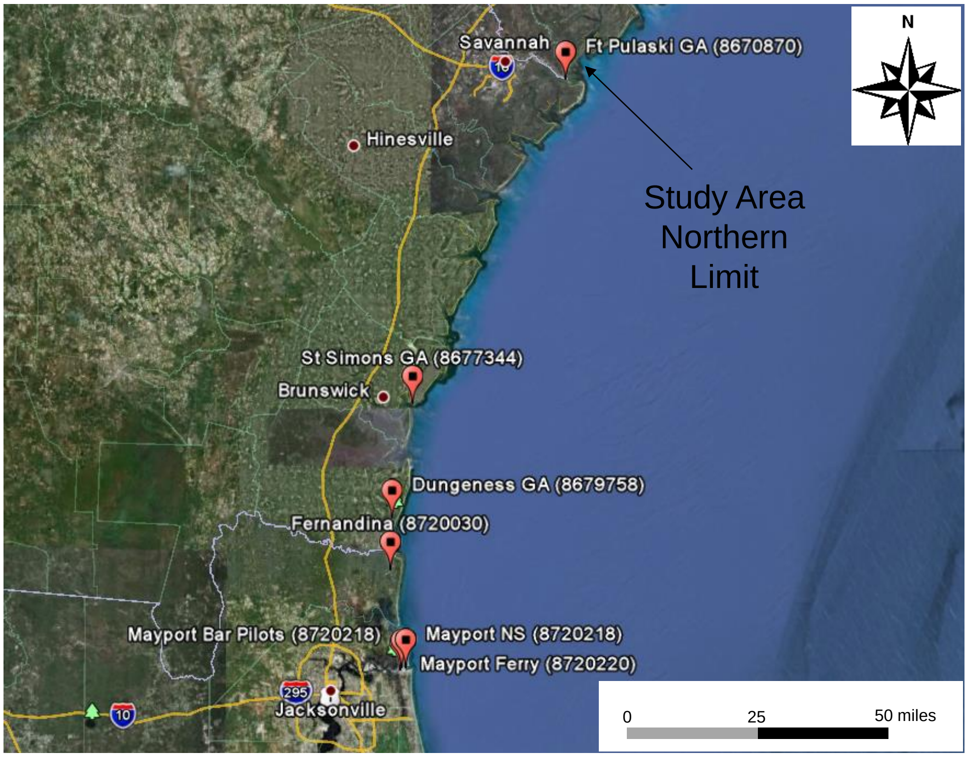

Figure 2 Georgia and North Florida NOAA Stations

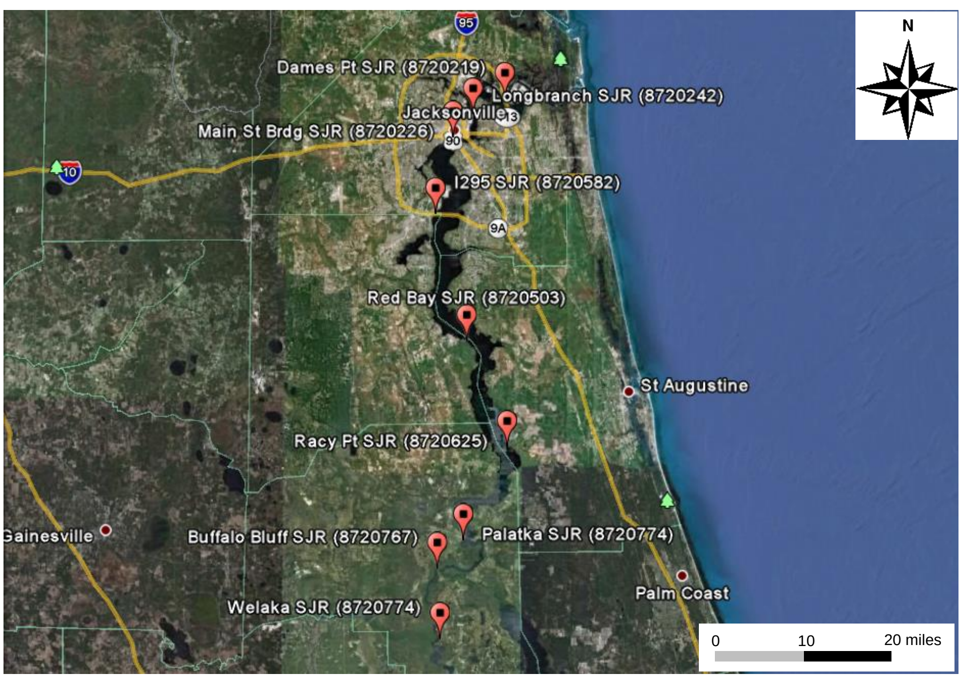

Figure 3 St. Johns River NOAA Stations

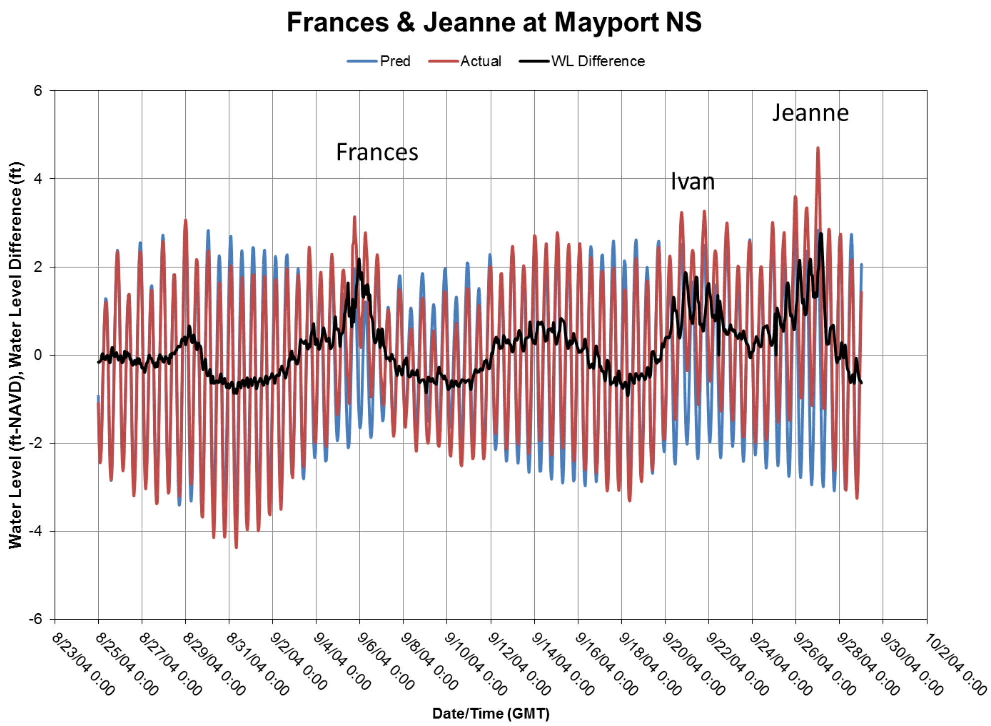

Figure 4 Total Water Levels at Mayport Naval Station during Hurricanes Frances and Jeanne (BakerAECOM, 2012)

Selection of Storms for Model Calibration and Validation

Table 2 shows the approximate maximum storm surge recorded by water level gages at Fernandina (about 20 miles north of the mouth of St. Johns River) and at various locations in the St. Johns River. The only significant hurricanes that made landfall at or near the project area are Dora and David. Dora caused the largest storm surges recorded at the mouth of St. Johns River (see Table 2). Compared to Dora, David caused less surge in the project area. At first glance, both Dora and David appear the best choice for model validation; however selecting the two storms is not ideal because

- Dora and David occurred 30 – 50 years ago; data availability is sparse and possibly of unknown accuracy
- The bathymetry used in the present modeling application does not reflect the bathymetry during the times of Dora and David; in particular, the St. Johns River entrance has been mechanically deepened about 10 – 20 feet since Dora and David

In spite of the above, the model calibration/validation process still included one storm (Dora) from nearly 50 years ago since Dora generated the largest storm surge for which historical measurements exist.

Table 2 Approximate Storm Surge at Fernandina and Along St. Johns River for Five Storms (derived from BakerAECOM, 2012)

NOAA Station	Approximate Maximum Storm Surge, ft				
	Dora 1964	**David 1979**	**Frances 2004**	**Tammy 2005**	**Fay 2008**
Fernandina	5.9	3	2.5	3	4
Mayport NS			2.2		
Mayport Bar Pilot			2.2	2.3	3
Mayport Ferry	4.1	2.8			
Main Street			3		
I295			3	2.5	3.7
Red Bay			2.6	2.3	
Racy Point			2.2		
Palatka			1.9		
Buffalo Bluff			1.7	1.4	

The other three storms caused relatively similar storm surges in the project area. Given that, the second storm identified for model calibration/validation is the storm with the most water level information in St. Johns River — Hurricane Frances.

Hurricane Dora Maximum Water Surface Elevation Data

In addition to data measured by the three NOAA tide gages, the GANEFLSSS searched and located water level data from post-Hurricane Dora reports. Though no agency appears to have conducted a systematic high water mark (HWM) collection following the storm, the GANEFLSSS culled official records and post-storm reports for an additional 11 HWMs of variable accuracy. Table 3 presents the high water values, with their sources and evaluation.

Hurricane Frances Maximum Water Surface Elevation Data

The GANEFLSSS collected measured water level data from 15 verified NOAA tide gage records with data available for Hurricane Frances. No agency appears to have conducted a systematic HWM collection within the GANEFLSSS project area. Table 4 presents the high water values at each NOAA gage location.

Summary

The present study will apply water level data for Hurricanes Dora and Frances to calibrate and verify the ADCIRC + SWAN model.

Table 3 Hurricane Dora High Water Marks

Location	Measured Water Elevation (Ft-NAVD)	Measured Source	Notes
Ft. Pulaski, GA (8670870)	5.0	NOAA-verified hourly tide record	
Fernandina Beach, FL (8720030)	6.7	NOAA preliminary hourly tide record	Source is unverified and contradicted by other sources that suggest up to 9 ft-NAVD tide
Mayport Ferry Slip, FL	6.2	USWB (1964)	Report does not specify datum. Level assumes 1964 MSL.
Mayport Ferry Depot, FL (8720220)	4.3	NOAA verified hourly tide record	Maximum from record appears questionable due to other source information.
Ribault River at Mouth	4.9	COJ and USACE (1980)	MSL datum transformed to NAVD
Millers Creek at Atlantic Blvd	5.7	Brand (2009)	Datum in NGVD transformed to NAVD
Downtown Jacksonville, St. Johns River	4.6	Brand (2009)	Datum in NGVD transformed to NAVD
McCoys Creek at mouth, St. Johns River	4.7	COJ and USACE (1980)	MSL datum transformed to NAVD
McCoys Creek at Stockton Street	6.3	Brand (2009)	Datum in NGVD transformed to NAVD
Fuller Warren Bridge, St. Johns River	5.5	COJ and USACE (1980)	MSL datum transformed to NAVD
Lower reach of Ortega River	5.8	COJ and USACE (1980)	MSL datum transformed to NAVD
NAS Jacksonville, St. Johns River	5.5	COJ and USACE (1980)	MSL datum transformed to NAVD
Anastasia Island, St. Augustine	7.0	NOAA (1964)	Questionable datum
Daytona Beach	5.9	Dunn (1965)	MSL datum transformed to NAVD

Table 4 Hurricane Frances (2004) High Water Marks from Verified NOAA Tide Records

Location	Measured Water Elevation (ft-NAVD)
Ft. Pulaski, GA (8670870)	3.9
St. Simons Lighthouse, GA (8677344)	3.9
Fernandina Beach, FL (8720030)	3.8
Mayport Naval Station, FL (8720218)	3.1
Mayport Bar Pilots Dock, FL (8720218)	2.9
Main St. Bridge, FL (8720226)	3.1
I295 Bridge, FL (8720582)	3.0
Red Bay Point, FL (8720503)	2.6
Racy Point, FL (8720625)	2.5
Palatka, FL (8720774)	3.0
Buffalo Bluff, FL (8720767)	2.8
SR-312 Matanzas R., FL (8720582)	3.9
Crescent Beach, FL (8720651)	4.2
Bings Landing, FL (8720757)	3.3
Trident Pier, FL (8721604)	3.7

Hydrodynamic Modeling for Storm Surge and Sea Level Change:

Jacksonville Harbor Navigation Study

Appendix D: Summary of Calibration and Validation Results

Duval County, FL

July 2013

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ADCIRC+SWAN STORM SURGE MODELING FOR JACKSONVILLE HARBOR NAGIVATION CHANNEL DESIGN

Task Order No. 01, Submission 7.3:

SUMMARY OF CALIBRATION AND VALIDATION RESULTS

Matthew V. Bilskie[1], E.I. and Scott C. Hagen, Ph.D., P.E.[2]

Coastal Hydroscience Analysis, Modeling, & Predictive Simulations Laboratory

CHAMPS Lab

http://champs.cecs.ucf.edu

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Stands For Opportunity

Revised Sept. 2013

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EXECUTIVE SUMMARY: This report summarizes the results obtained by the calibration and validation of the coupled ADCIRC+SWAN hydrodynamic and wind-wave numerical model for simulation of currents and water levels in Jacksonville Harbor. The results from the ADCIRC+SWAN model calibration and validation form the basis of this summary report.

ADCIRC+SWAN MODEL DOMAIN REPRESENTATION: ADCIRC (Advanced CIRCulation) is a finite element-based model that permits the use of unstructured meshes (Luettich and Westerink, 2006). SWAN (Simulating WAves Nearshore) solves the action balance equation and is tightly coupled with the ADCIRC model to operate on the same unstructured mesh. SWAN is forced by winds, water levels, and currents passed from ADCIRC, where it computes a new water level (Dietrich *et al*, 2011). The unstructured finite element mesh was developed based on an adaptation of a local mesh of the lower St. Johns River and the FEMA Northeast Florida Georgia (NEFLGA) storm surge mesh (Figure 1 and Figure 2). Figure 3 presents the mesh topography and bathymetry for the lower St. John's River and associated floodplain.

Landcover Data: A C-CAP land cover raster dataset was obtained from the C-CAP Land Cover Atlas (http://www.csc.noaa.gov/ccapatlas/). The resolution of the dataset is 30 m.

Surface Roughness Parameters: The landcover data were used to define three surface roughness parameters within the study area: Manning's *n*, surface canopy, and surface directional effective roughness length (Z_0) (Table 1). Figure 4 through Figure 6 show the spatially varying Manning's *n* coefficients, surface canopy, and Z_0 from due east wind.

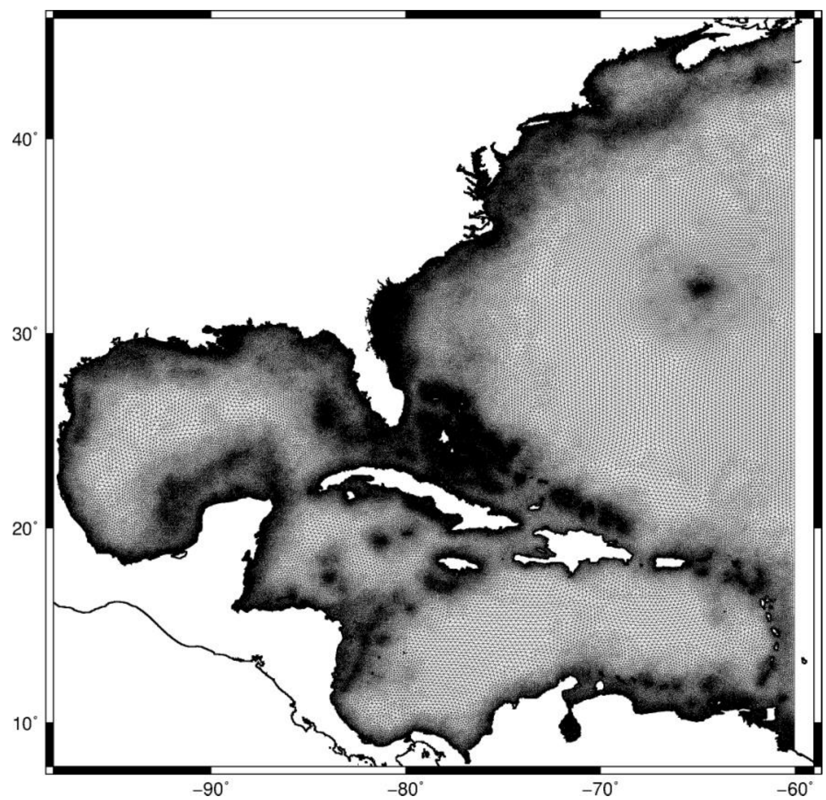

Figure 1 ADCIRC+SWAN unstructured finite element mesh

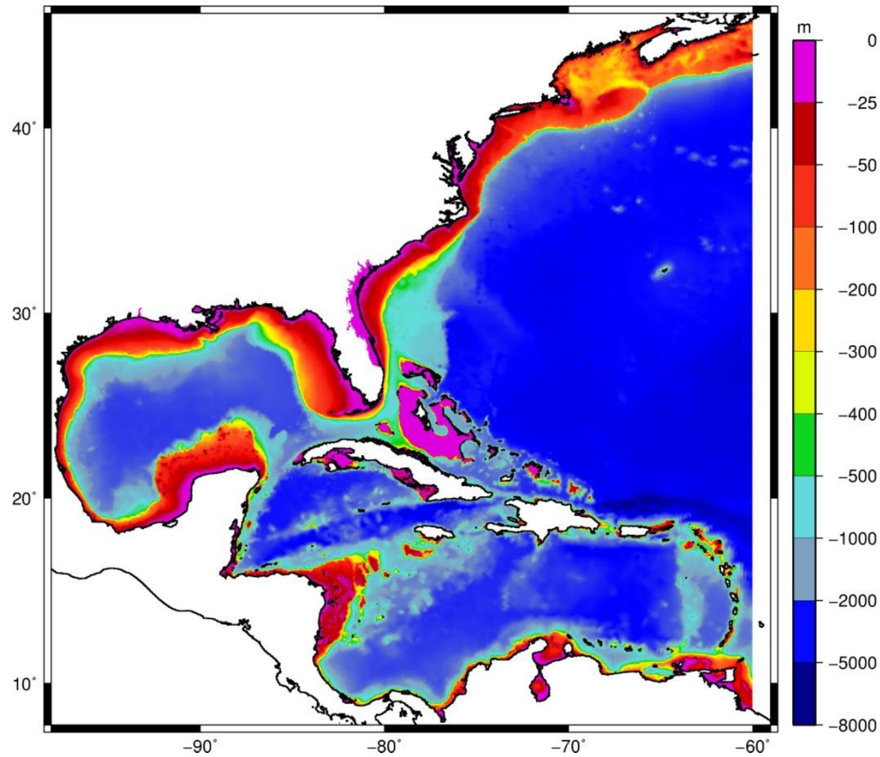

Figure 2 Mesh bathymetry

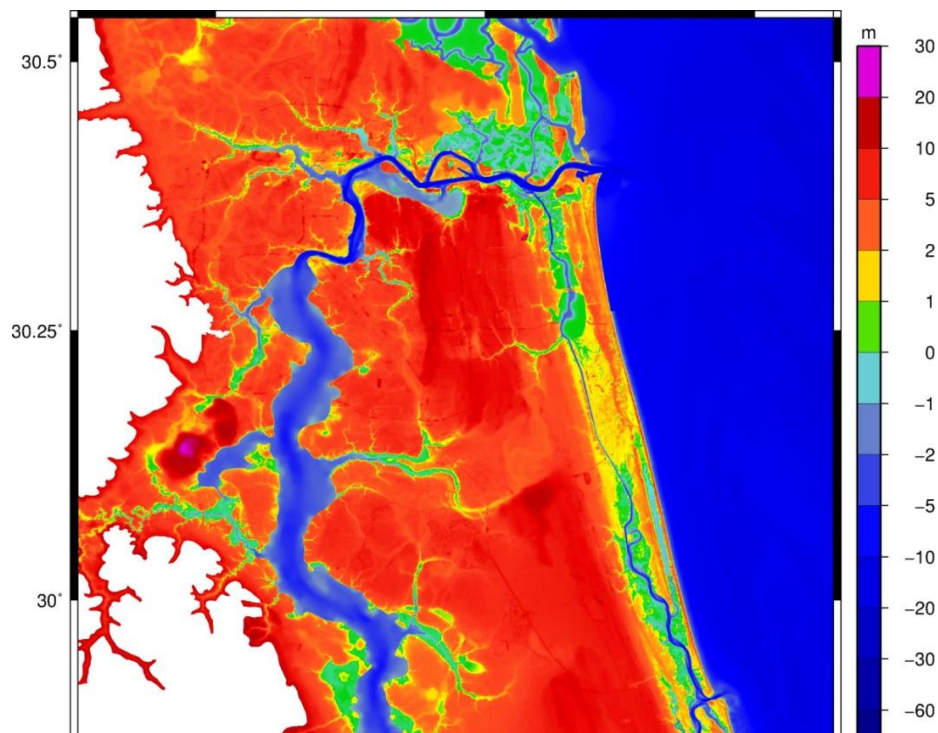

Figure 3 Lower St. Johns River mesh topography and bathymetry

Table 1 Surface roughness look up tables associated with C-CAP land cover

C-CAP Class	Class Description	Manning's *n*	Surface Canopy	Z0
2	High-Intensity developed	0.150	1	0.550
3	Medium-intensity developed	0.100	1	0.400
4	Low-intensity developed	0.050	1	0.300
5	Developed open space	0.020	1	0.100
6	Cultivated land	0.037	1	0.060
7	Pasture/hay	0.033	1	0.060
8	Grassland	0.034	1	0.040
9	Deciduous forest	0.100	0	0.650
10	Evergreen forest	0.110	0	0.720
11	Mixed forest	0.100	0	0.710
12	Scrub/shrub	0.050	1	0.120
13	Palustrine forested wetland	0.100	0	0.550
14	Palustrine scrub/shrub wetland	0.048	0	0.120
15	Palustrine emergent wetland	0.045	1	0.110
16	Estuarine forest wetland	0.100	0	0.550
17	Estuarine scrub/shrub wetland	0.048	1	0.120
18	Estuarine emergent wetland	0.045	1	0.110
19	Unconsolidated shore	0.040	1	0.090
20	Bare land	0.090	1	0.040
21	Open water	0.020	1	0.001
22	Palustrine aquatic bed	0.015	1	0.030
23	Estuarine aquatic bed	0.015	1	0.030

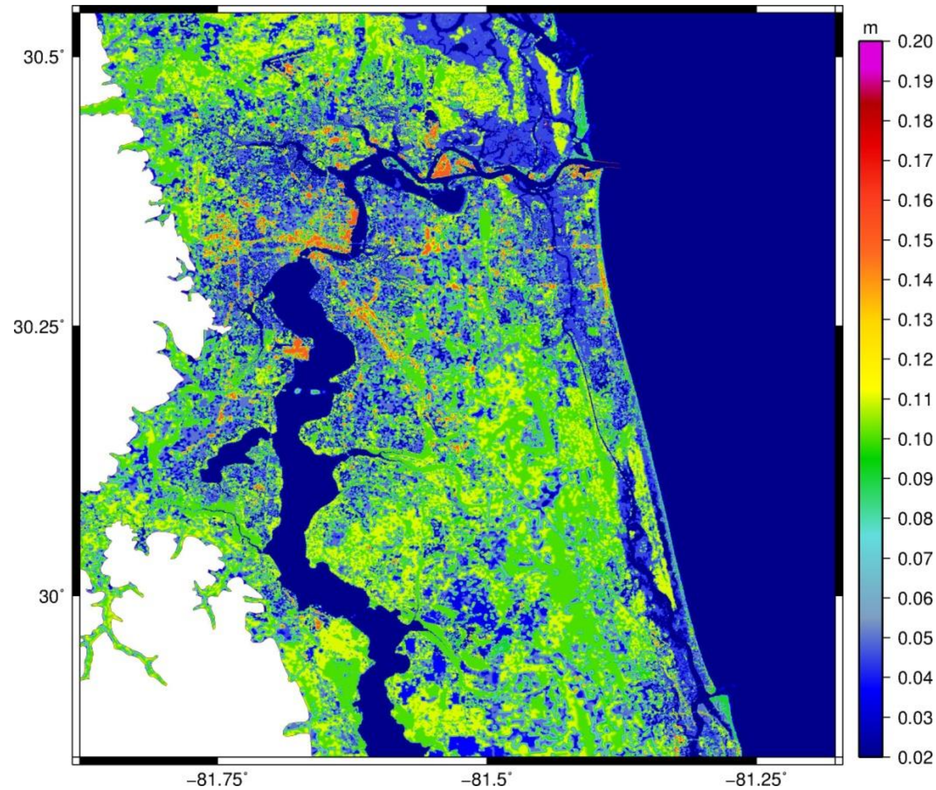

Figure 4 Lower St. Johns River Manning's *n*

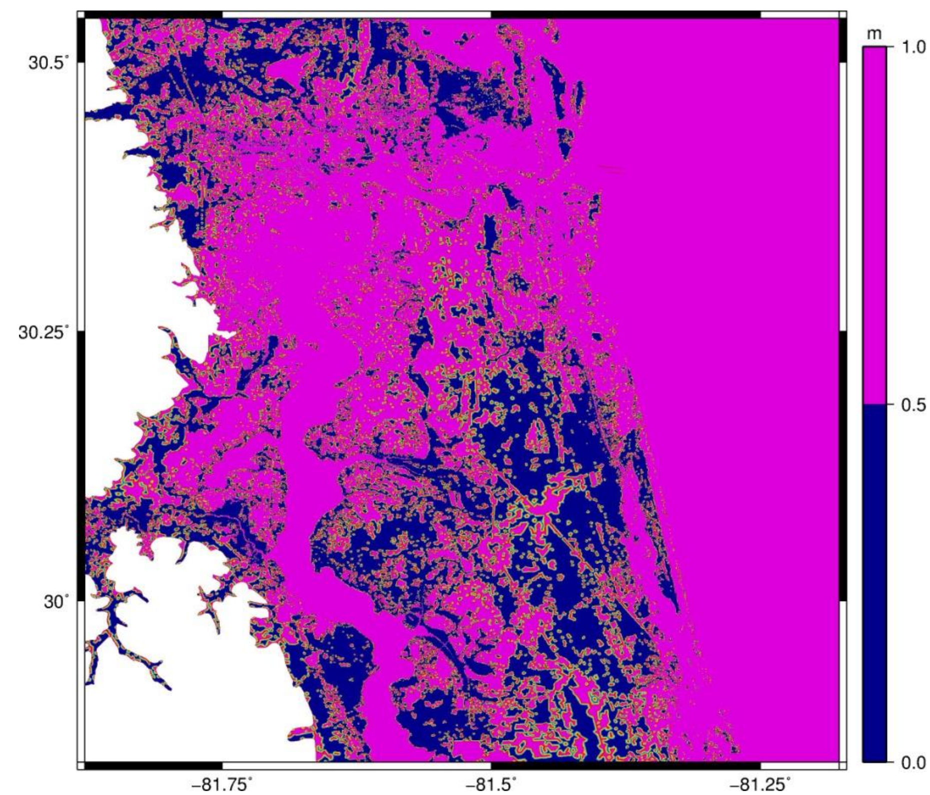

Figure 5 Lower St. Johns River surface canopy (winds are "turned off" at values of 0)

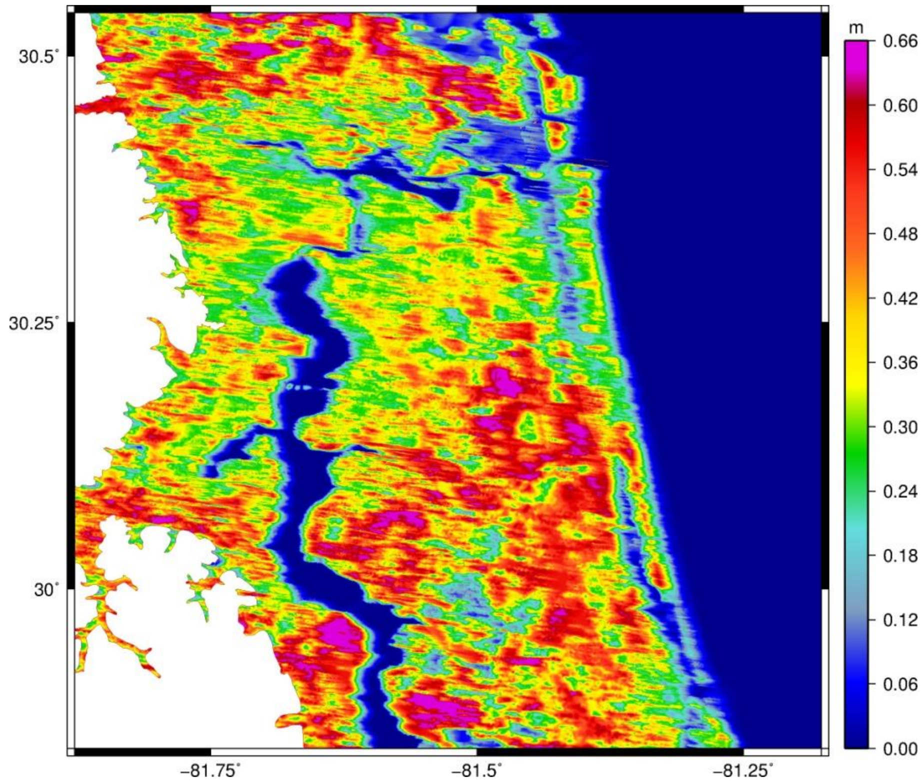

Figure 6 Lower St. Johns River surface directional effective roughness length (Z_0) for a due east wind.

VALIDATON: Two storm events were used to validate the ADCIRC+SWAN numerical model, Hurricane Dora (1964) and Hurricane Frances (2004) (Figure 8 and Figure 9) by comparing observed time-series water levels at three gages during Dora and fourteen during Frances (Figure 7). For each event, a 15-day astronomic tidal-spinup was performed before introducing the wind field to the model. Table 2 illustrates the simulation dates for each storm event.

ADCIRC+SWAN run parameters are presented in Table 3. All run parameters are equivalent between the simulations except the initial sea surface state [used to represent the current sea state during a particular time period and is equal to the steric effect + conversion between NAVD88 and mean sea level (MSL)]. The offset for Hurricane Dora is -16 cm and for -21 cm for Hurricane Frances. The offset for Hurricane Frances was obtained by averaging the average water levels at NOS Station 8720218 (Mayport, FL) for three time spans before the landfall; one month, two weeks, and one week Table 4.

Validation Plots: Figure 10 through Figure 12 present time-series water level plots at three water level stations for Hurricane Dora. Figures 13 through 26 present water level stations for Hurricane Frances. The modeled water levels generally agree with the observed data. Tidal phase and amplitude are captured well along with the peak surge and recession limb of the surge hydrograph. Given, the changes in bathymetry and topography since Hurricane Dora and the difficulty in developing an accurate two-dimensional wind and pressure field from a storm that occurred over 50 years ago, differences between the modeled and measured values are not unexpected. Model skill is less at the upstream portions of the river; however, the model is not forced with river inflow.

Table 2 ADCIRC+SWAN simulation dates for tidal spinup and wind and wave forcing.

Storm Event	Begin Tidal Spinup	Wind Forcing Begin	Wave Forcing Begin	End Simulation Day
Dora	08-20-1964 00:00 UTC	09-03-1964 00:00 UTC	09-03-1964 00:00 UTC	09-12-1964 00:00 UTC
Frances	08-15-2004 00:00 UTC	08-30-2004 00:00 UTC	08-30-2004 00:00 UTC	09-08-2004 00:00 UTC

Table 3 ADCIRC+SWAN run parameters

	Parameter	Value
ADCIRC	Time Step	1 sec
	FFACTOR	0.0025
	H0	0.1
	Velmin	0.05
	ANGINN	110
	Wind Drag	Garratt
	Wind Drag Limit	0.0035
SWAN	Time Step	1200 sec
	Friction	Madsen
	Max Iterations	20

Table 4 Comparison of average sea states before Hurricane Frances

	Begin	End	Average Water Level (m-NAVD88)
Month	8/1/2004	8/31/2004	-0.19
2 Weeks	8/14/2004	8/31/2004	-0.24
1 Week	8/21/2004	8/31/2004	-0.21
		Average	**-0.21**

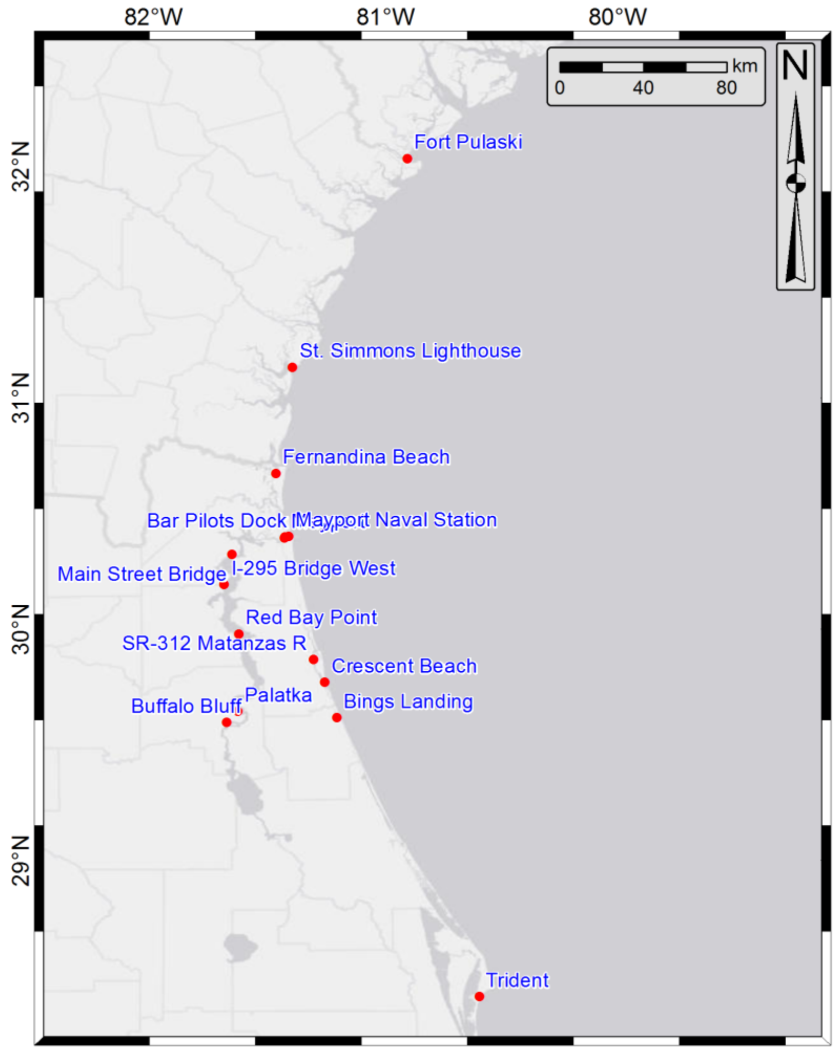

Figure 7 Location of water levels gages used for validation (Dora and Frances)

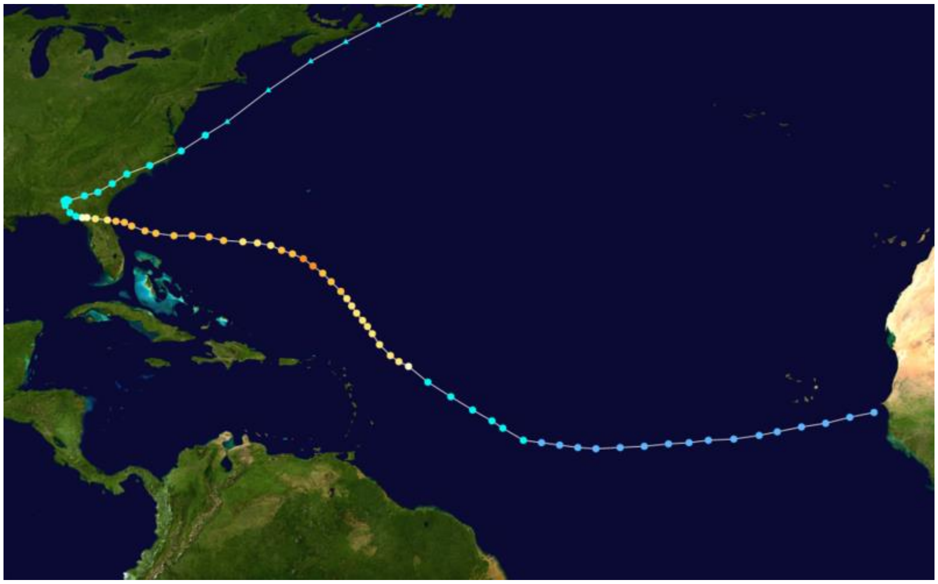

Figure 8 Hurricane Dora (1964) track

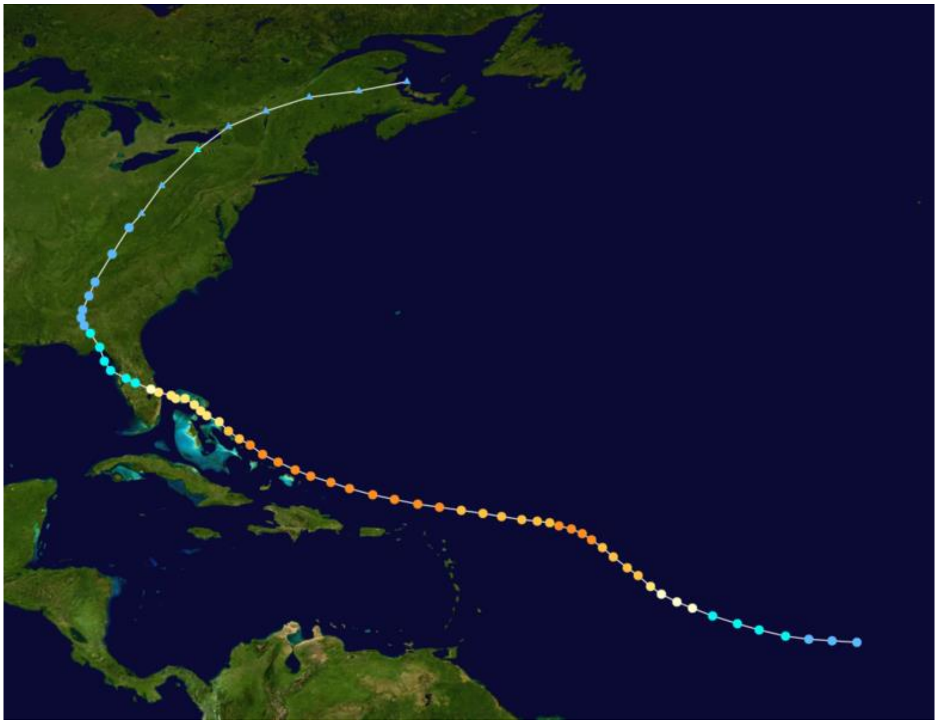

Figure 9 Hurricane Frances (2004) track

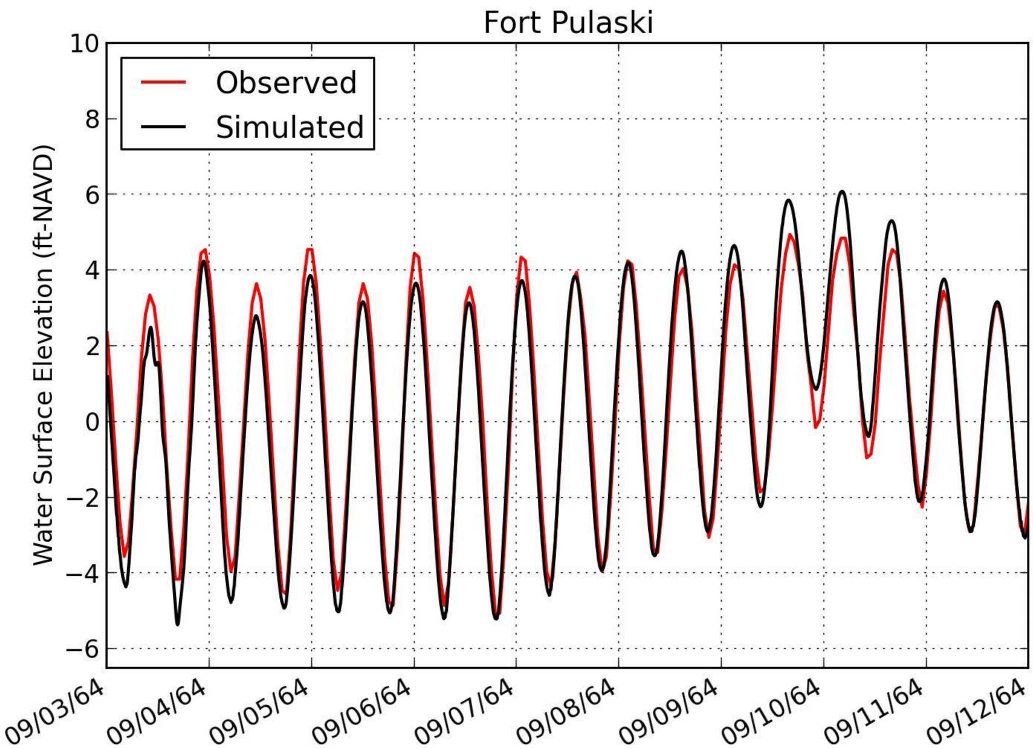

Figure 10 Time series plots of water levels (observed versus simulated) at Fort Pulaski for Hurricane Dora

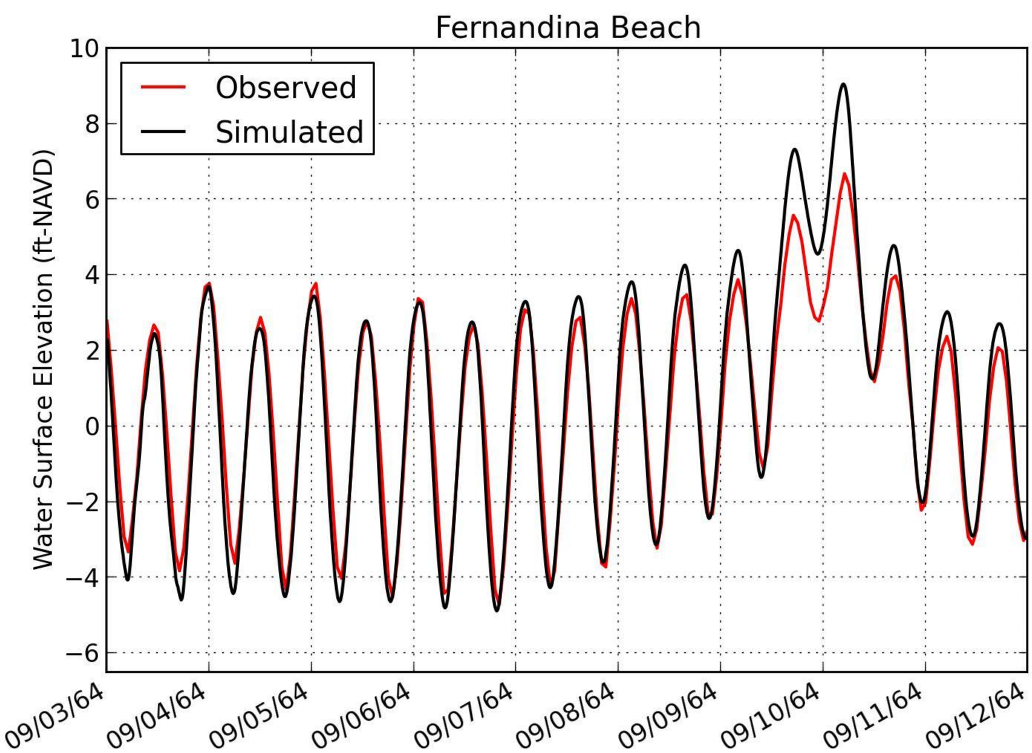

Figure 11 Time series plots of water levels (observed versus simulated) at Fernandina Beach for Hurricane Dora

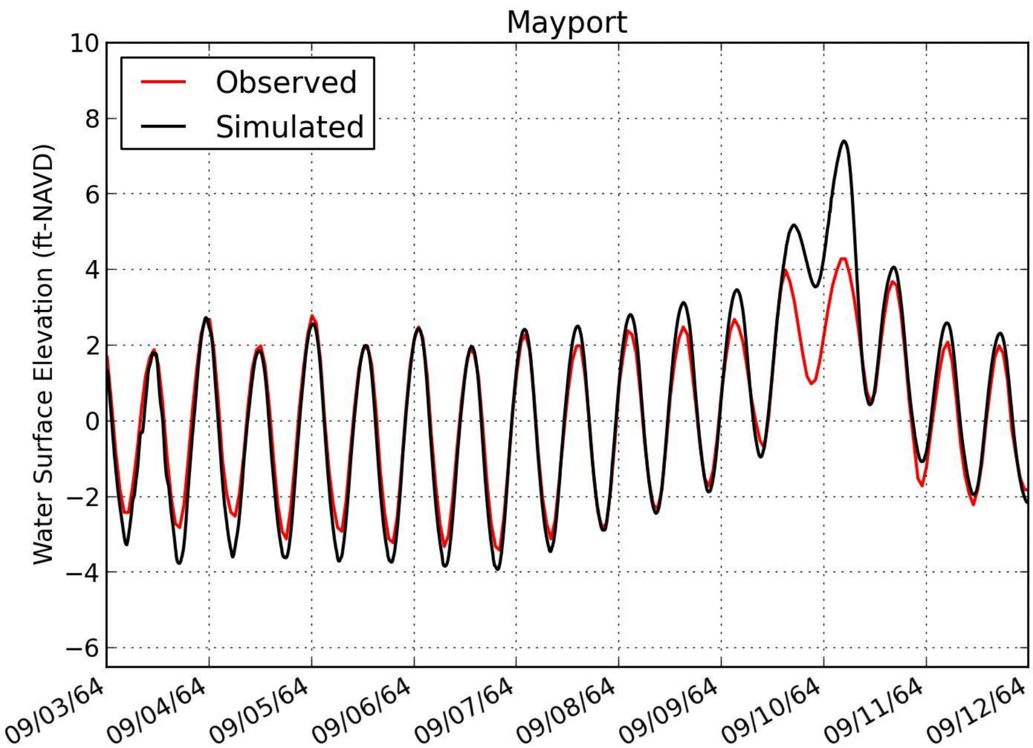

Figure 12 Time series plots of water levels (observed versus simulated) at Mayport for Hurricane Dora

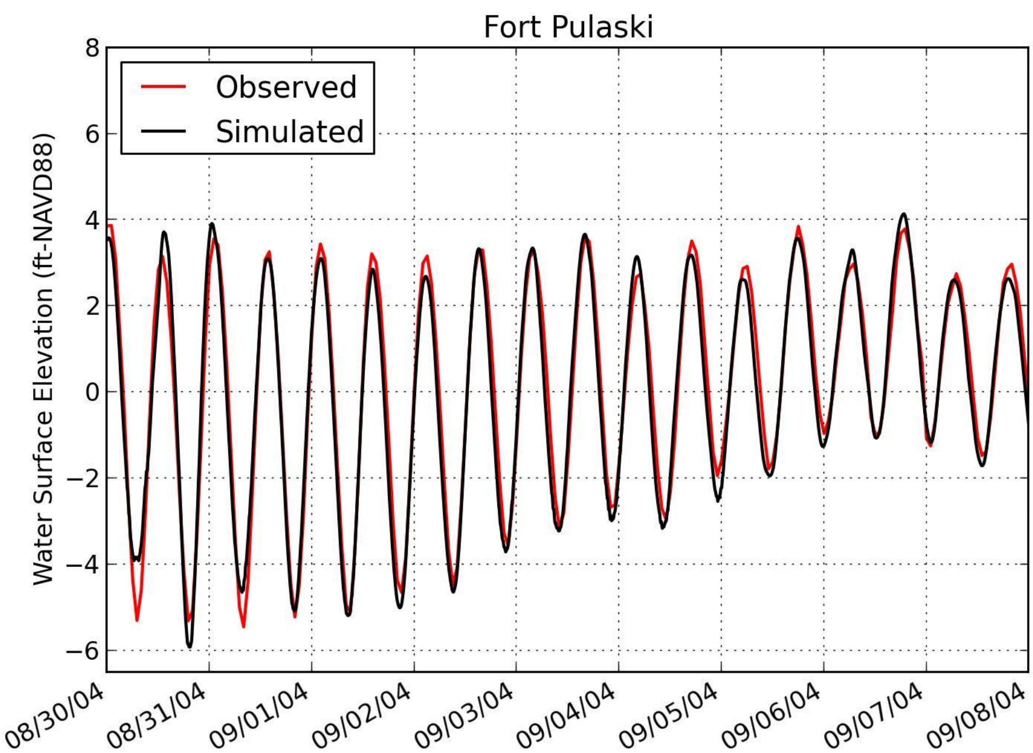

Figure 13 Time series plots of water levels (observed versus simulated) at Fort Pulaski for Hurricane Frances

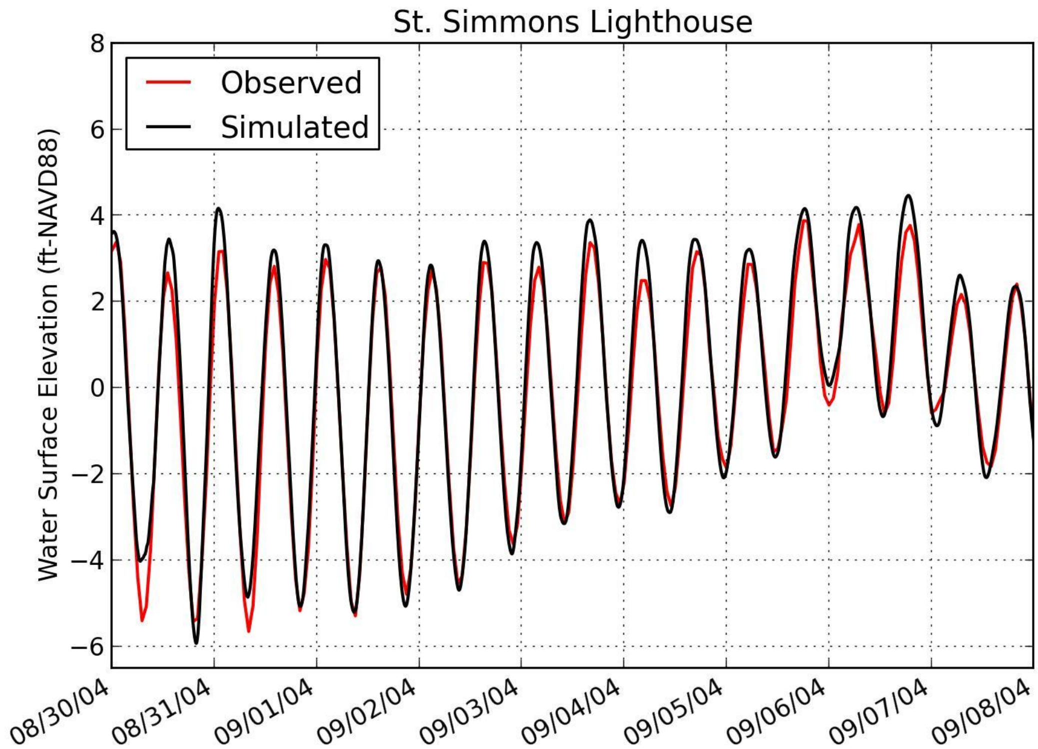

Figure 14 Time series plots of water levels (observed versus simulated) at St. Simmons Lighthouse for Hurricane Frances

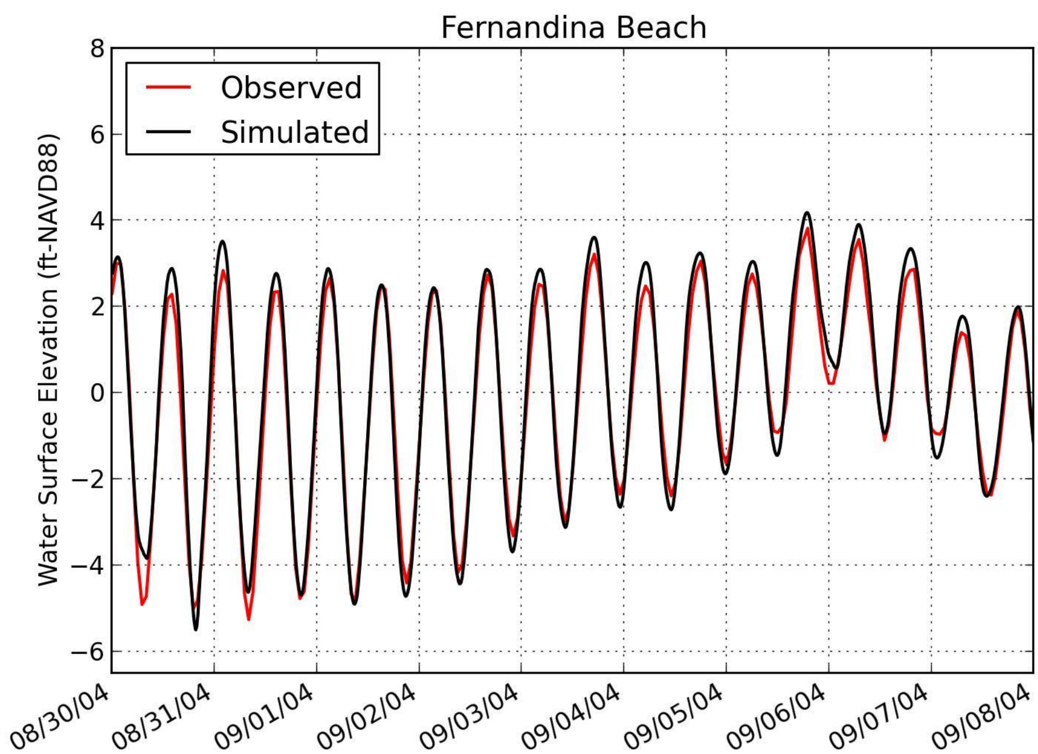

Figure 15 Time series plots of water levels (observed versus simulated) at Fernandina Beach for Hurricane Frances

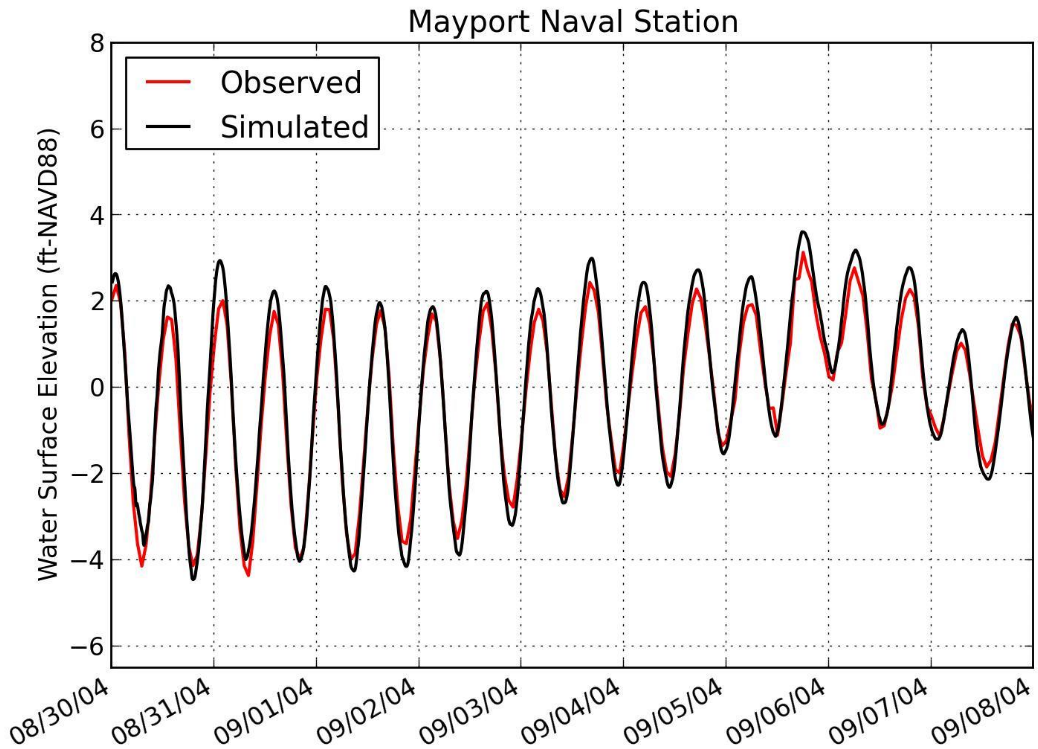

Figure 16 Time series plots of water levels (observed versus simulated) at Mayport Naval Station for Hurricane Frances

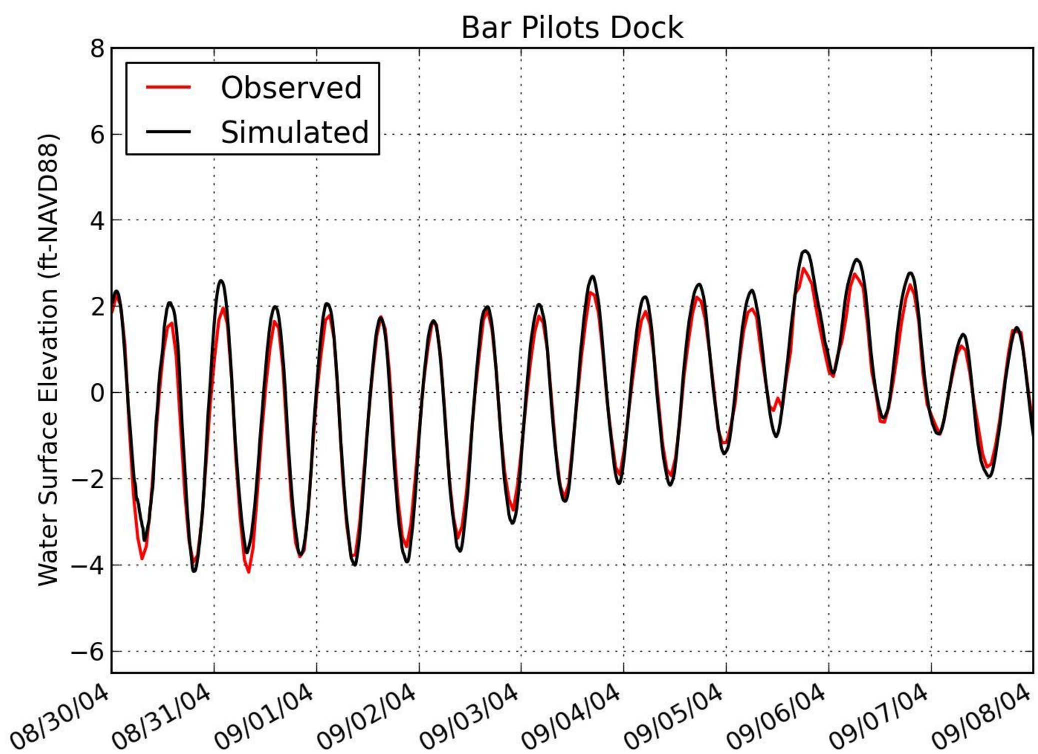

Figure 17 Time series plots of water levels (observed versus simulated) at Bar Pilots Dock for Hurricane Frances

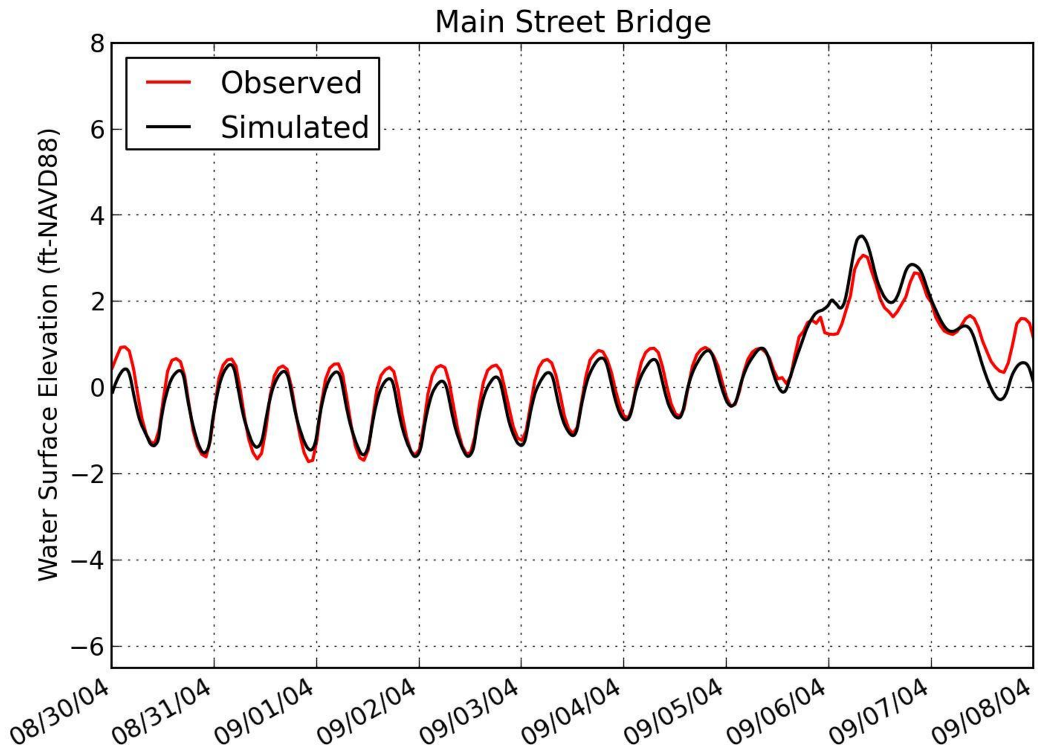

Figure 18 Time series plots of water levels (observed versus simulated) at Main Street Bridge for Hurricane Frances

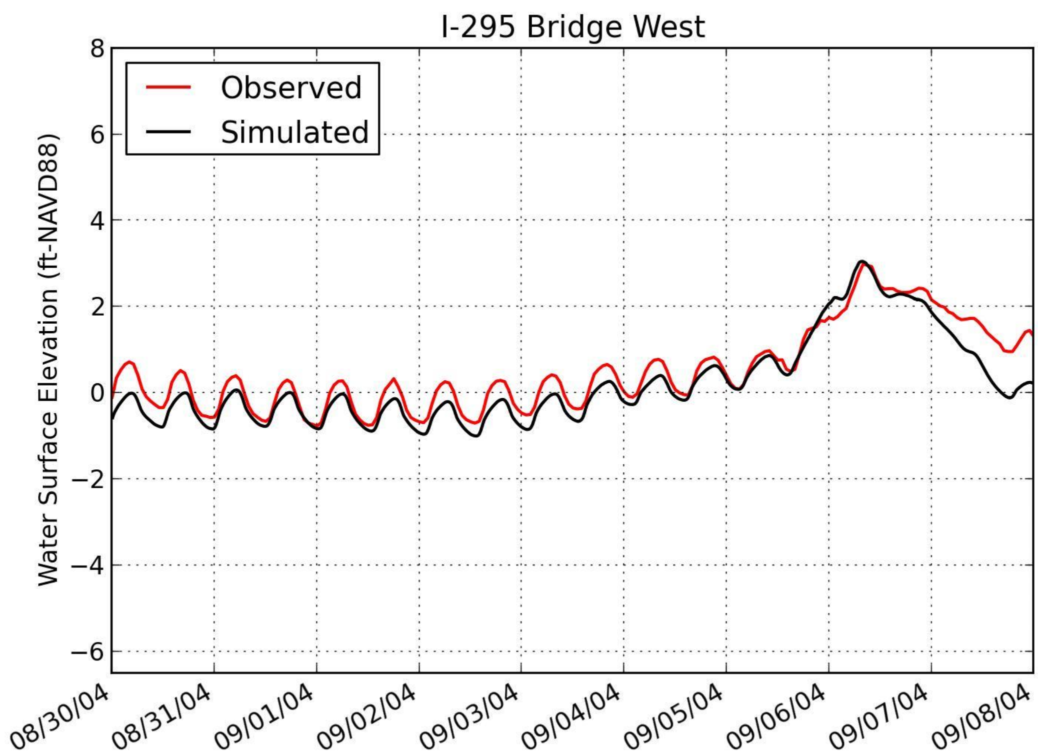

Figure 19 Time series plots of water levels (observed versus simulated) at I-295 Bridge West for Hurricane Frances

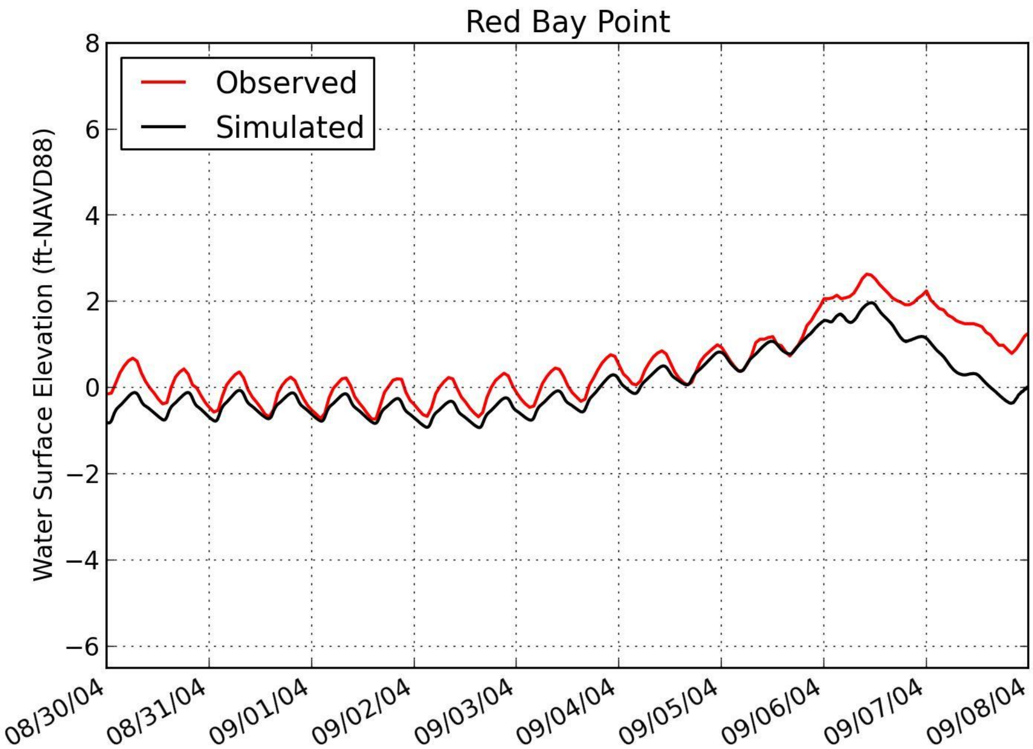

Figure 20 Time series plots of water levels (observed versus simulated) at Red Bay Point for Hurricane Frances

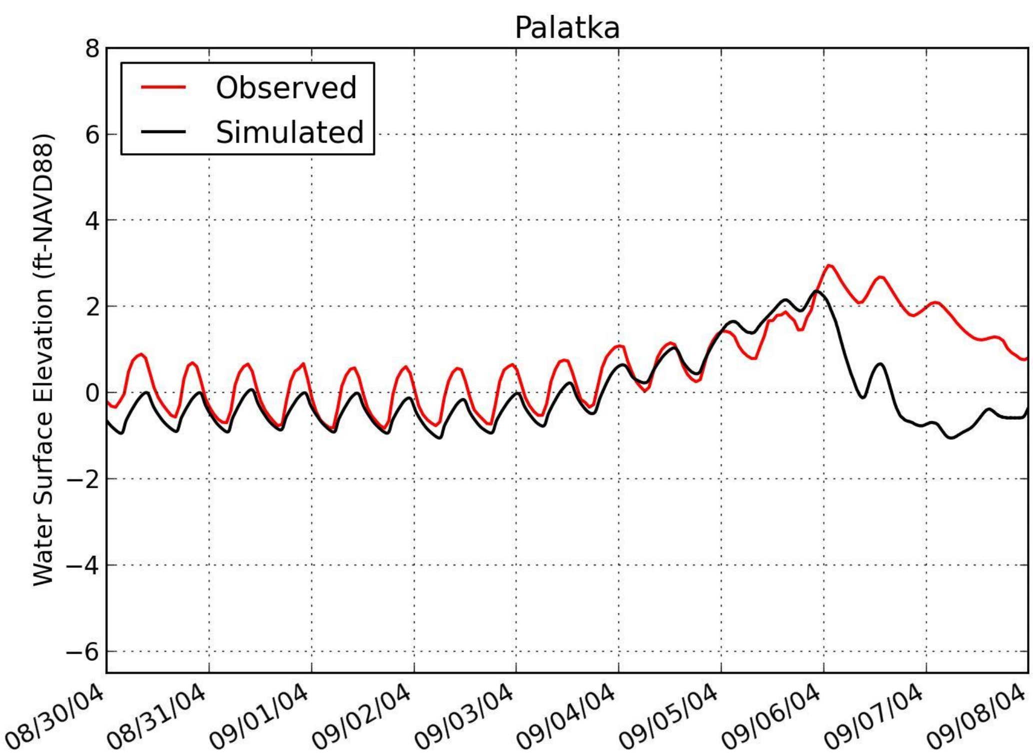

Figure 21 Time series plots of water levels (observed versus simulated) at Palatka for Hurricane Frances

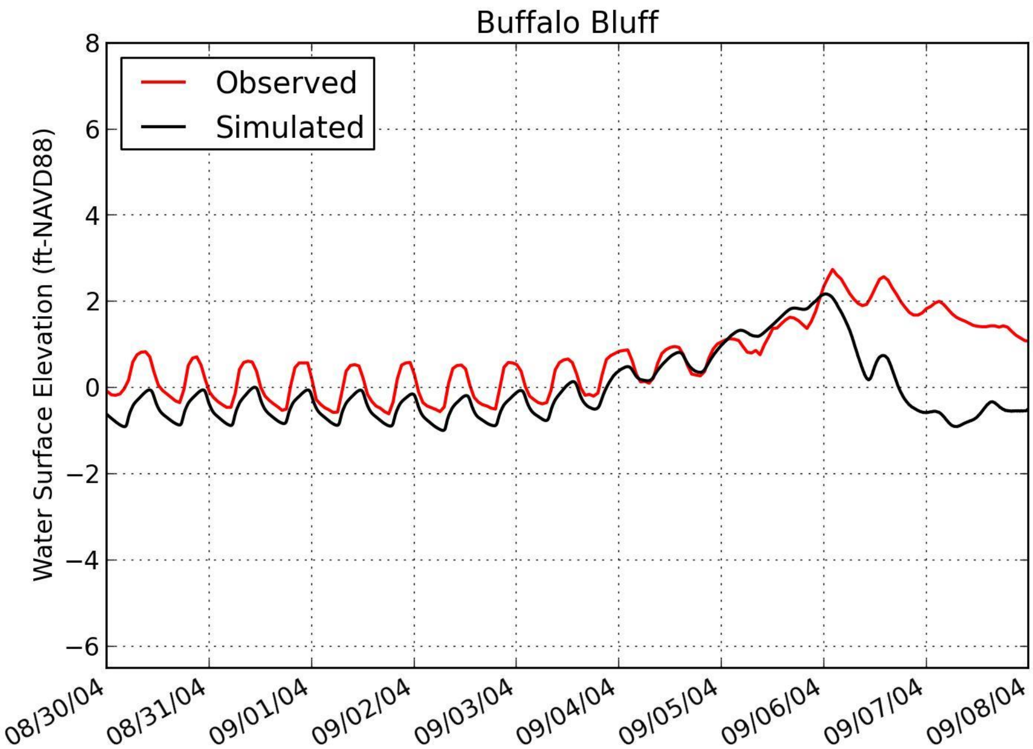

Figure 22 Time series plots of water levels (observed versus simulated) at Buffalo Bluff for Hurricane Frances

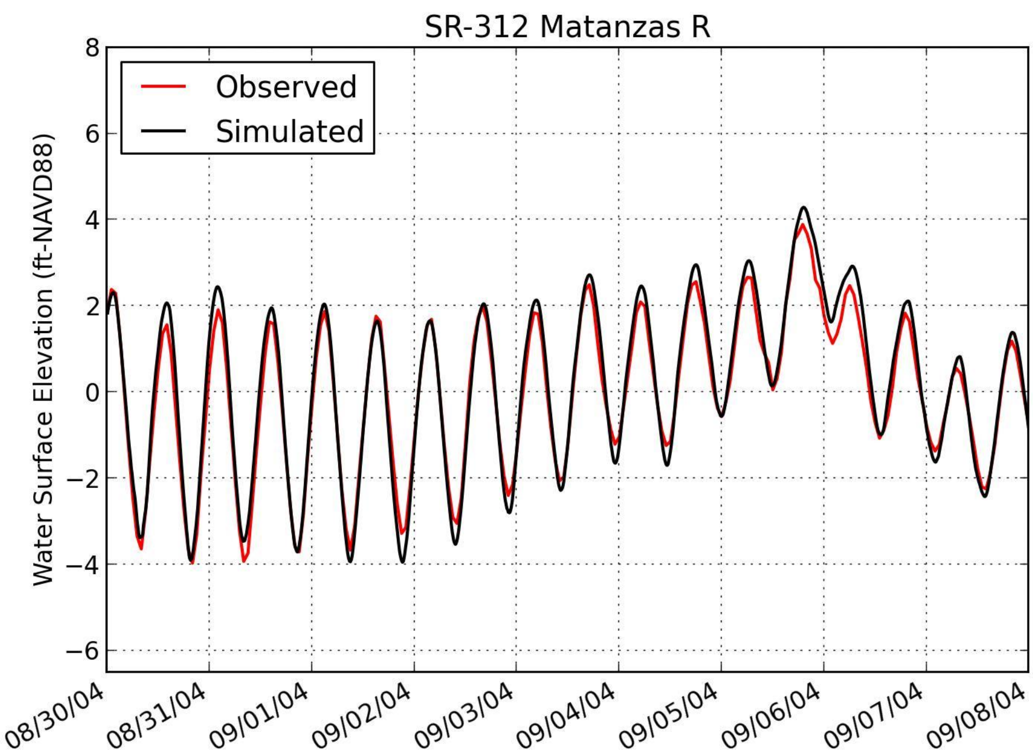

Figure 23 Time series plots of water levels (observed versus simulated) at SR-312 Matanzas for Hurricane Frances

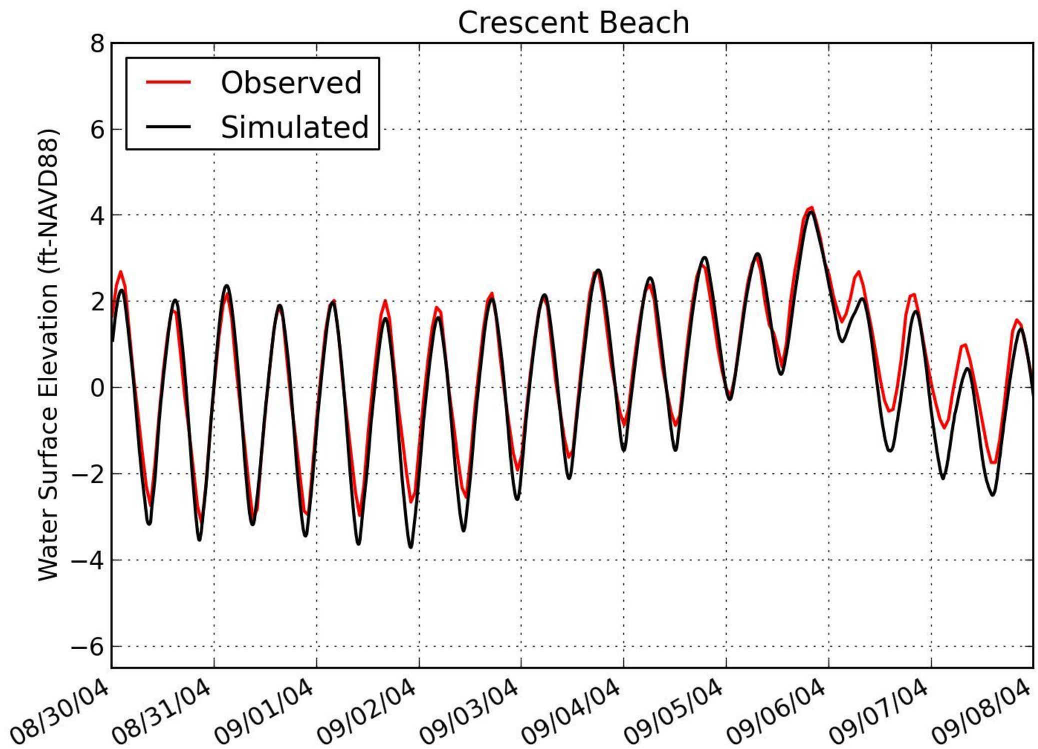

Figure 24 Time series plots of water levels (observed versus simulated) at Crescent Beach for Hurricane Frances

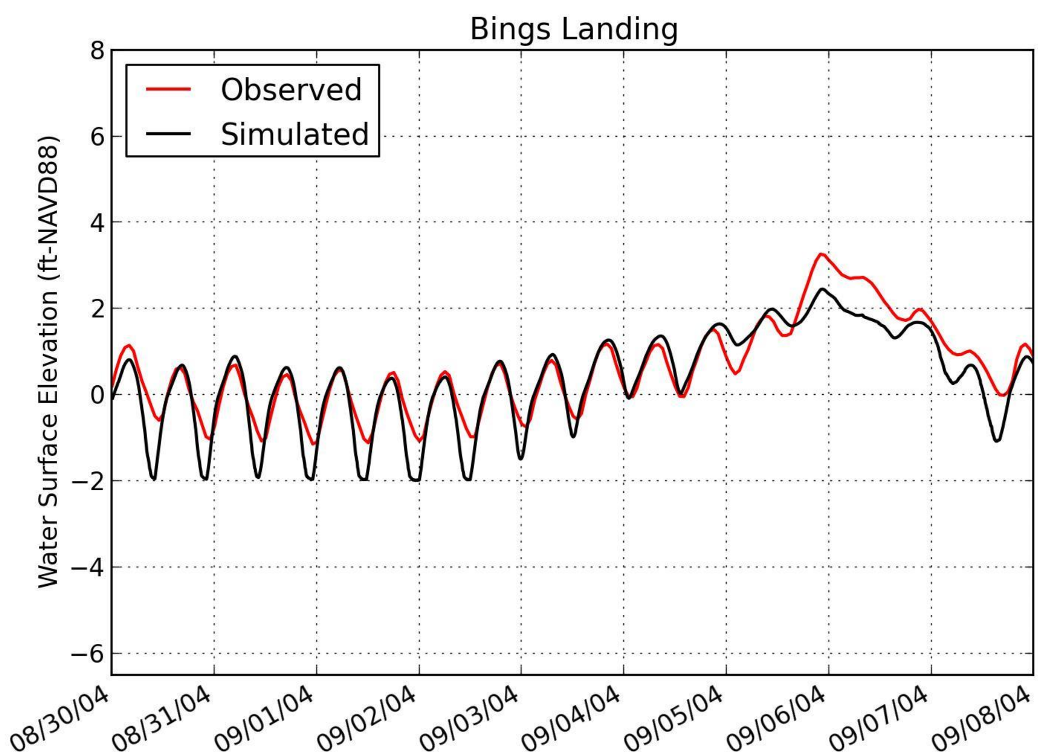

Figure 25 Time series plots of water levels (observed versus simulated) at Bings Landing for Hurricane Frances

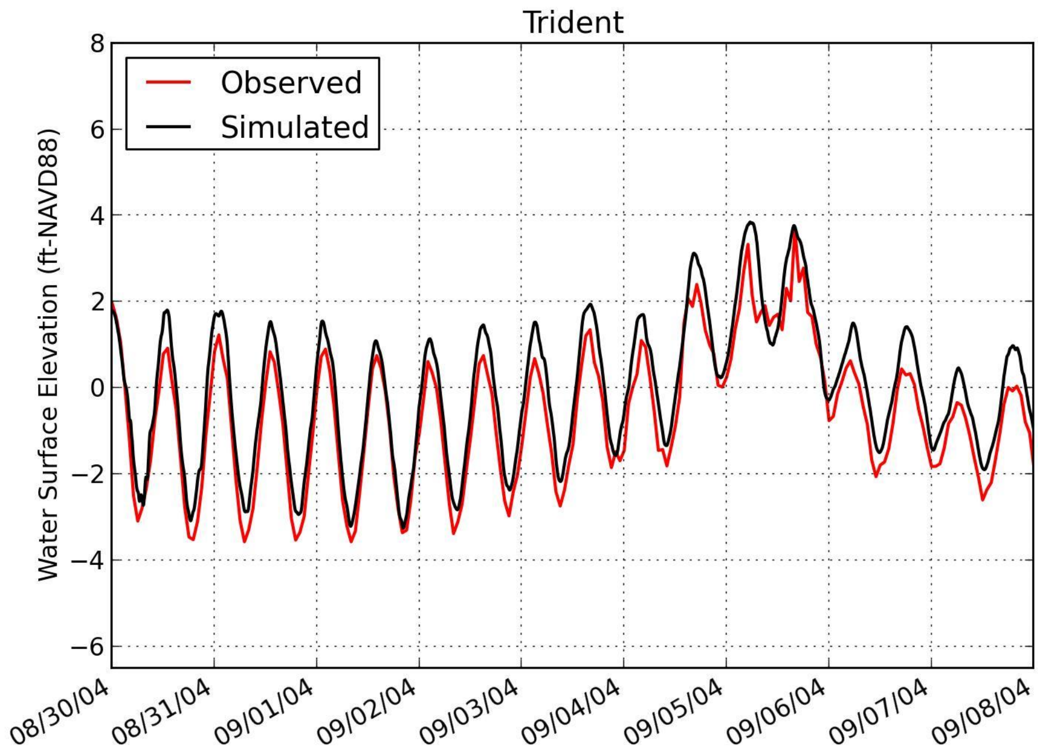

Figure 26 Time series plots of water levels (observed versus simulated) at Trident Pier for Hurricane Frances

REFERENCES:

Dietrich, J. C., Zijlema, M., Westerink, J. J., Holthuijsen, L. H., Dawson, C. N., Luettich, R. A., Stone, G. W. (2011). Modeling hurricane waves and storm surge using integrally-coupled, scalable computations. *Coastal Engineering, 58*, 45-65.

Luettich, R. A., Westerink, J. J., & Scheffner, N. W. (1992). ADCIRC: An Advanced Three-Dimensional Circulation Model For Shelves, Coasts, and Estuaries, I: Theory and Methodology of ADCIRC-2DDI and ADCIRC-3DL: U.S. Army Corps of Engineers.

Hydrodynamic Modeling for Storm Surge and Sea Level Change:

Jacksonville Harbor Navigation Study

Appendix E: Development of 50- and 100-year Storm Events for ADCIRC+SWAN Model Simulations

Duval County, FL

July 2013

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Development of 50- and 100-yr Storm Events for ADCIRC+SWAN Model Simulations

Prepared for

U.S. Army Corps of Engineers, Jacksonville District

by

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May 2013

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1.0 INTRODUCTION

The ADCIRC+SWAN Storm Event Modeling for Jacksonville Harbor Navigation Channel Design study requires application of synthetic storms that produce 50- and 100-year water levels near the project. In this study, we define the 50- and 100-yr storm events as those that produce 50- and 100-yr water levels offshore of the entrance to the Jacksonville Harbor Navigation Channel. Application of the model forcing that produces 50- and 100-year water levels in the ADCIRC + SWAN model allows evaluation of existing and alternative channel configurations for follow-on efforts. In addition, application of various sea level change scenarios in combination with the model forcing and channel configurations allows evaluation of future scenarios.

Figure 1.1 provides the major features of the Jacksonville Harbor Navigation Channel and surrounding area. The figure shows mile markers, location of the Federal channel, and major landmarks near the channel.

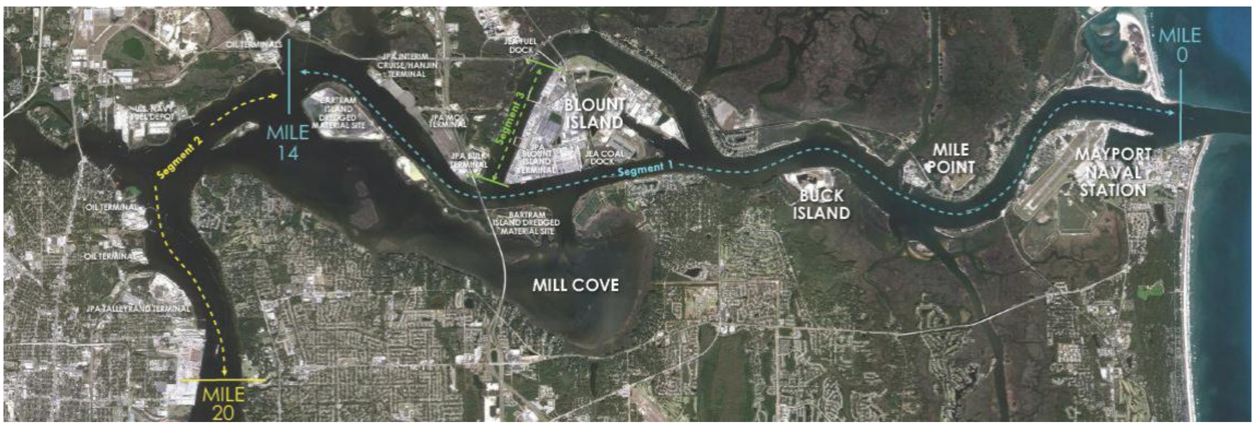

Figure 1.1 Jacksonville Harbor Navigation Channel Features.

2.0 DEVELOPMENT OF TARGET WATER LEVELS

The synthetic storm development focused on selecting forcing parameters within the ADCIRC+SWAN model that produce 50- and 100-yr water levels in the Jacksonville Harbor Navigation Channel. Dean et al. (1991) provided the 50- and 100-yr water levels offshore of the project area. Dean et al. developed the total storm tide values for various return periods along three shore-perpendicular transects in Duval County, FL. The total storm tide estimates include the contributions of wind stress, barometric pressure, dynamic wave setup, and astronomical tide.

Using the Dean et al. (1991) water levels presents several benefits over using the existing Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) water level values in the project vicinity. First, because the FEMA FIS study numerical modeling occurred in the middle to late 1980s, the Dean et al. data provide results from a more recent analysis. Second, Dean et al. include a robust calculation for the effects of nearshore waves on the water levels. Though the FEMA FIS values contain wave-induced water level change (setup) for offshore locations, the procedure applied by the FEMA study remains uncertain. Third, Sheppard and Miller (2003) found that the Dean et al. data provides higher 50- and 100-yr water levels for coastal areas around Florida as compared to the FEMA FIS values. Sheppard and Miller also reviewed ADCIRC modeling conducted for northern Duval County that showed

50- and 100-yr water levels closer to the Dean et al. values than the FEMA FIS values, especially for the 50-yr level. Therefore, the Dean et al. values provide a reasonably conservative value as compared to the FEMA FIS data. The FEMA FIS data do contain values for inshore locations, closer to the middle of the Jacksonville Harbor Navigation Channel project. However, the FEMA FIS values do not include wave-induced water level changes (setup) at these locations.

Figure 2.1 shows the location of the three transects applied in Dean et al. (1991). Dean et al. developed water levels for various return periods at each transect. Table 1 shows the total storm tide values for various return periods along the three transects applied in Duval County. Notably, Table 2.1 presents levels in NGVD (feet, ft). The conversion between NGVD and NAVD88 at the project site equals 1.15 ft (0 ft-NAVD88 = 1.15 ft-NGVD). The Jacksonville Harbor Navigation Channel Design study area occurs approximately halfway between the Dean et al. North and Middle profiles. Notably, minimal variation (0.1 ft) occurs between the two profiles for the 50- and 100-yr total storm tide levels, which reduces the importance of the exact location of the channel between the profiles.

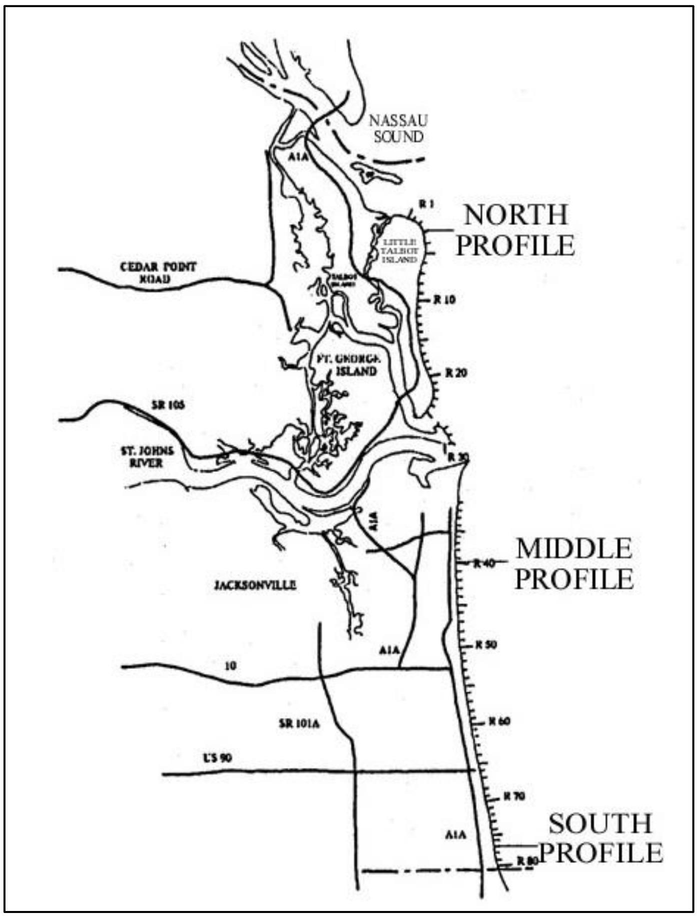

Figure 2.1 Location of Transects Applied in Duval County Total Storm Tide Analysis (Dean et al., 1991; FSU Beaches and Shores Resource Center website; http://beach10.beaches.fsu.edu/duval.html)

Table 2.1 Total Storm Tide for Various Return Periods along the Three Transects Applied in Duval County
(Dean et al., 1991; FSU Beaches and Shores Resource Center website)

Return Period	Combined Total Storm Tide Level* above NGVD (ft.)		
TR (years)	North Profile	Middle Profile	South Profile
500	17.8	17.9	17.8
200	15.1	15.3	15.3
100	13.1	13.2	13.2
50	10.6	10.5	10.5
20	7.1	6.9	6.9
10	5.3	4.9	5
5	4.2	3.9	3.9
*Includes contributions of wind stress, barometric pressure, dynamic wave setup, and astronomical tide			

To develop the target 50- and 100-yr water levels, the study team selected the Middle profile values and then converted to the NAVD88 datum to compare with the calibrated and validated ADCIRC+SWAN model. The resulting 50- and 100-yr water levels equal 9.4 and 12.0 ft-NAVD88. These water levels provided the target water levels for the ADCIRC+SWAN model results in the offshore area near the mouth of the St. Johns River.

Development of Storm Parameters

To meet the target 50- and 100-yr water levels, the study team applied variations of the Hurricane Dora (1964) wind and pressure fields. Hurricane Dora made landfall south of the Jacksonville Harbor Navigation Channel Design study area, near St. Augustine, Florida. The ADCIRC+SWAN model applied the Hurricane Dora wind and pressure fields along with measured water level data during the model calibration and validation exercise. Offshore of the Jacksonville Harbor Entrance, the calibrated and validated ADCIRC+SWAN with Hurricane Dora forcing produced water levels around 9.2 ft-NAVD — below the 50- and 100-yr target water levels. Therefore, development of target 50- and 100-yr water levels required modification of the storm track and wind speeds. Shifting the Hurricane Dora storm track northward by 2 miles produced a maximum ADCIRC+SWAN model water level offshore of the Jacksonville Harbor Entrance equal to 9.4 ft-NAVD. This shifted Hurricane Dora forcing provides the 50-yr water level in the vicinity of the project area.

To develop the 100-yr water level within the ADCIRC+SWAN model, the study shifted the Hurricane Dora track by 8 miles and increased the wind speeds by a factor of 1.25. Shifting the storm northward without increasing wind speeds could not raise the ADCIRC+SWAN model water levels offshore of the Jacksonville Harbor Entrance above approximately 9.7 ft-NAVD88. Shifting the storm track and increasing the wind speeds via the ADCIRC+SWAN *DWM* parameter allowed the ADCIRC+SWAN model to develop water levels equal to 12 ft-NAVD88. The ADCIRC model documentation defines the *DWM* parameters as "specifying a multiplication factor for the wind velocities." Figures 2.2 and 2.3 present the maximum ADCIRC+SWAN water elevations (ft-NAVD88) for the 50- and 100-yr storms as developed for this study. As expected, the water level diminishes from the offshore area moving landward. 50- and 100-yr storm event water levels near the mid-point of the Jacksonville Harbor Navigation Channel Design study area reach approximately 7 and 10 ft-NAVD88. For reference, Figure 2.4 presents the ADCIRC+SWAN maximum water elevations (ft-NAVD88) for the Hurricane Dora (1964) model validation simulation. The simulated Hurricane Dora maximum water levels are similar to those for the 50-yr forcing shown in Figure 2.2.

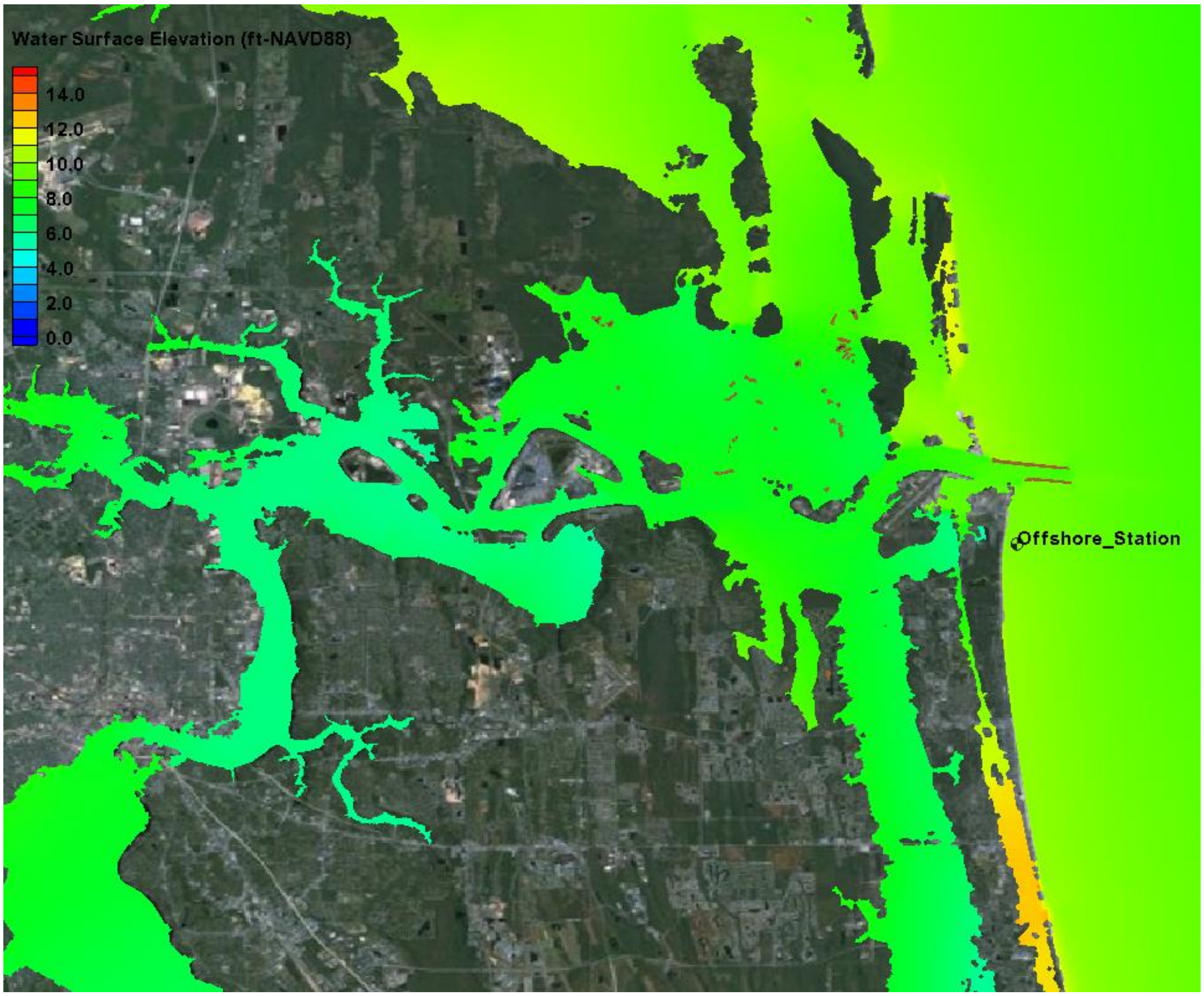

Figure 2.2 Maximum Water Surface Elevations from the ADCIRC+SWAN Model Simulation of the Selected 50-yr Water Level Storm

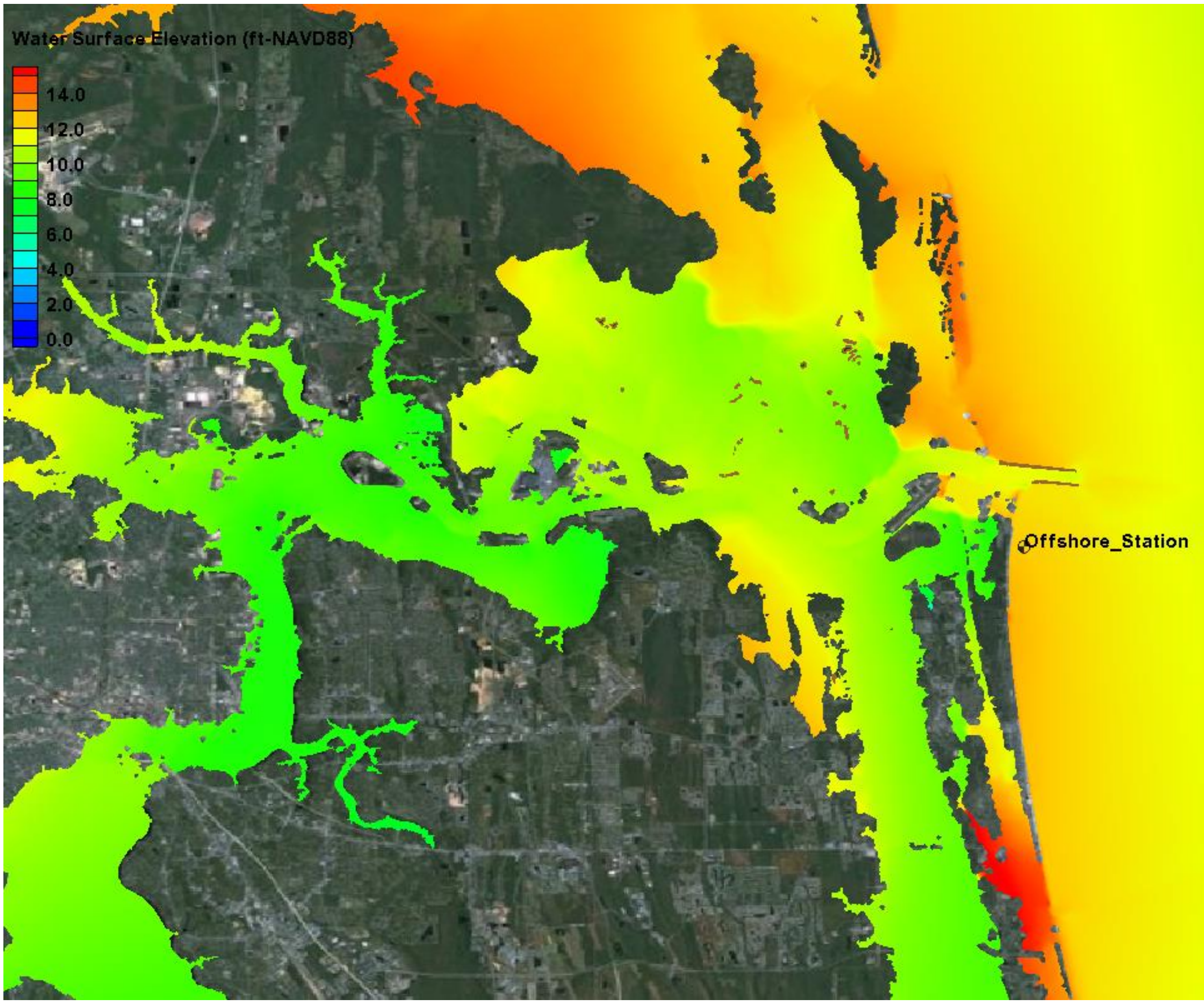

Figure 2.3 Maximum Water Surface Elevations from the ADCIRC+SWAN Model Simulation of the Selected 100-yr Water Level Storm

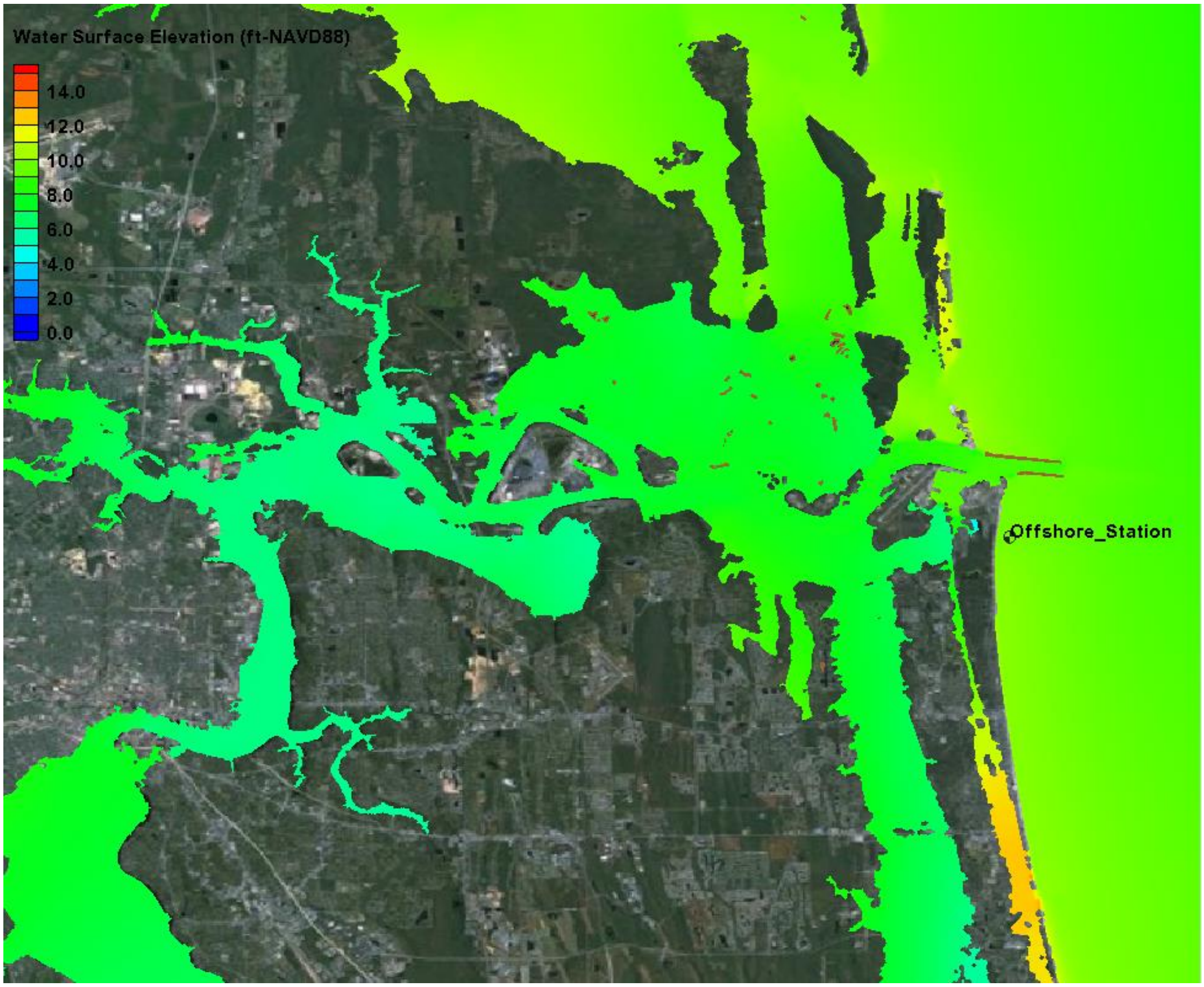

Figure 2.4 Maximum Water Surface Elevations from the ADCIRC+SWAN Model Simulation of Hurricane Dora (1964)

3.0 FUTURE WORK

This portion of the study has established the ADCIRC+SWAN model forcing conditions for the 50- and 100-yr storm events. The study team will apply these storm forcing conditions within modified ADCIRC+SWAN models which reflect various Jacksonville Harbor Navigation Channel configurations and sea level rise scenarios. A comparison of the base model maximum water level results to those of the modified models will demonstrate any potential effects of the channel configuration and sea level on the storm surge. In addition, ADCIRC+SWAN model output saved at specific locations will provide boundary condition data for additional modeling efforts.

4.0 REFERENCES

Dean, R.G., Chiu, T.Y., and Wang, S.Y. 1991. Combined Total Storm Tide Frequency Analysis for Duval County, Florida. Submitted to the Beach and Shores Resource Center, Institute of Science and Public Affairs, Florida State University, Tallahassee, FL.

Sheppard, D.M. and Miller, W. 2003. Design Storm Surge Hydrographs for the Florida Coast; Final Report. Submitted to the Florida Department of Transportation, Tallahassee, FL.